

# Implementation of Energy-efficient Axial Fans for Air Handling Unit Using AI Model

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## Abstract

*This research explores the integration of energy-efficient axial fans in Air Handling Units (AHUs) within a large automotive manufacturing facility to enhance HVAC (heating, ventilation, and air conditioning) performance and reduce energy consumption. Standard AHUs in the facility's clean rooms and other spaces utilize traditional blower fans, which primarily rely on static pressure, limiting their efficiency. By replacing these with electronically commutated (EC) axial flow fans, which leverage both static and dynamic pressures, the system's overall efficiency is improved significantly. The new axial fans achieve over 85% efficiency, resulting in reduced energy consumption by 20-50%, lower operating costs, and a decrease in carbon emissions. Additionally, a CFM heat load calculation is employed to match fan ratings to clean room requirements, emphasizing precise temperature and humidity controls essential for quality manufacturing. A machine learning-based classification algorithm, with a focus on the decision tree model, is integrated to optimize airflow regulation by interfacing with edge gateway systems. This approach allows for accurate control of Variable Frequency Drives (VFD) in the AHUs, resulting in energy savings and system responsiveness. In addressing the specific cooling demands of the facility's clean rooms, this study demonstrates that implementing EC fans and advanced control algorithms can significantly enhance HVAC efficiency, support sustainable energy practices, and contribute to climate change mitigation. These findings underscore the potential for optimized AHU design and control to transform energy-intensive industrial environments.*

**Keywords:** Energy efficiency, classification algorithm, Building management system, Heat ventilation and air conditioning system, electronically commutated fans.

## INTRODUCTION

Energy efficiency in industrial air conditioning systems has become a priority in light of rising energy demands, particularly in energy-intensive regions like India. In automotive manufacturing facilities, Air Handling Units (AHUs) play a critical role in maintaining air quality and temperature control. Traditional AHUs, equipped with blower fans reliant on static pressure, often fail to achieve optimal efficiency. This study proposes implementing electronically commutated (EC) axial flow fans in AHUs to improve efficiency and reduce energy consumption. Additionally, a machine learning algorithm is employed to enhance airflow regulation, providing dynamic, high-precision control to suit clean room requirements in manufacturing environments.

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In energy-conscious India, where indoor activities consume more than 85% of people's time,

prioritizing energy efficiency is crucial due to significant energy consumption by buildings and industries. With a rapidly growing population and increasing energy demand, efficient energy utilization becomes imperative. Moreover, energy efficiency initiatives contribute to reducing carbon emissions and supporting global climate change mitigation. Air-conditioning systems, as defined by ASHRAE, must effectively manage air quality, movement, humidity, and temperature. Air Handling Units (AHUs), commonly found in commercial and industrial buildings, play a vital role in regulating and circulating air. These units consist of fans, motors, filters, heating and cooling coils, humidifiers, and dehumidifiers, enclosed within a sizable metal cabinet. Figure 1 illustrates a typical air handling unit situated in the mechanical room at the site, designed to optimize ventilation throughout the entire building [1].



**Figure 1.** Depicts a typical basic air handling unit located in the mechanical room within the facility.

The BidP plant, located in the Bidadi Industrial area near Bangalore, houses a large automotive parts manufacturing facility. Two production hangars, 101 and 102, require air-conditioning to maintain optimal temperature and humidity levels. To achieve this, each hangar is equipped with 16 large AHUs, along with smaller units for clean rooms, office areas, server rooms, and labs. An energy audit revealed that the total installed capacity of the 16 AHUs is 137.25 kW, with an average daily energy consumption of 3675 kWh [2].

To enhance the HVAC system's efficiency, this project focuses on installing energy-efficient axial flow fans in six AHUs dedicated to maintaining air conditioning in the clean rooms of Hangar 101. This approach incorporates high-efficiency fans (90% efficiency), high-efficiency motors (91% efficiency), and intelligent Variable Frequency Drives (98% efficiency). The flame-proof design ensures effective operation even at higher static heads (150-200 mm WC). Implementing this energy-efficient system can result in a minimum 35% reduction in energy consumption compared to the current fan power usage. Axial flow fans, utilizing both static and dynamic pressures, achieve efficiencies above 90%, outperforming plug, and centrifugal fans that waste dynamic pressure. With motor and frequency drive efficiencies exceeding 95% and fan and motor efficiency reaching 92%, the overall system efficiency reaches an impressive 85%. This makes the energy-efficient axial fan solution the most efficient option for AHUs, leading to lower operating costs and reduced carbon emissions compared to alternatives [3].

Improving energy efficiency in AHUs is crucial for sustainable development, cost reduction, and environmental preservation. It addresses India's growing energy demands and contributes to global efforts in combating climate change. Proper duct calculation is essential for ensuring efficient and effective operation of the HVAC system. In this project, calculations are performed for four zones and a mechanical room housing the AHU, considering factors such as building layout, HVAC system capacity, and desired airflow rates. Optimizing elements like pressure losses, air velocity, and static pressure enhances system performance. A Building Management System (BMS) or Building Automation System (BAS) is a computer-based control system that monitors and controls various building services and equipment, including lighting and HVAC systems. Its key objectives are optimizing building efficiency, reducing energy consumption, and ensuring occupant safety and comfort. A BMS consists of sensors, controllers, actuators, and communication protocols. It collects data, makes control decisions, allows remote monitoring and adjustment, generates reports, and aids in

problem diagnosis. Integrating and automating building systems through a BMS offers benefits such as energy savings, improved indoor air quality, occupant comfort, and reduced maintenance costs. The clean rooms in this project require precise temperature control to ensure the manufacturing of components without contamination or defects. To address temperature regulation issues, the project employs machine learning techniques, focusing on selecting an appropriate classification algorithm [4]. The decision tree algorithm proves most suitable for this problem. Integration with the edge gateway enables centralized control and management of the AHUs, allowing adjustment of the Variable Frequency Drive (VFD) to regulate airflow and achieve the desired temperature range. The research explores the effectiveness and practical implementation of the decision tree algorithm, emphasizing its compatibility with the existing HVAC system through edge gateway integration.

## METHODOLOGY

The research was conducted within a large automotive manufacturing plant located in the Bidadi Industrial area near Bangalore. This facility utilizes 16 AHUs in production hangars and additional units for offices and clean rooms. Six AHUs in clean rooms were selected for retrofitting with EC axial fans, which harness both static and dynamic pressures, yielding superior efficiency compared to conventional fans [5,6].

To determine the appropriate fan rating for each clean room, a Cubic Feet per Minute (CFM) heat load calculation was performed. Additionally, a classification algorithm, specifically a decision tree model, was applied to manage Variable Frequency Drives (VFDs) through an edge gateway system. This allowed for automatic adjustments to airflow based on real-time temperature and humidity data.

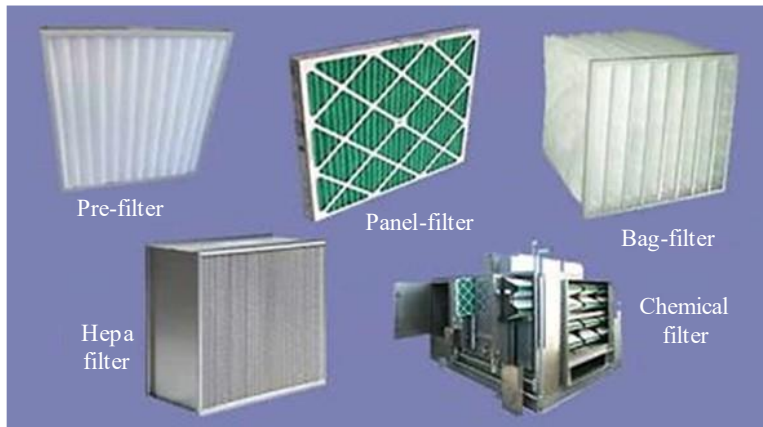
### Different Parts of the Air Handling Unit

- a. *Mixing Chamber*: The below Figure 2 visually portrays the mixing chamber incorporated within the air handling unit (AHU). This crucial component harmoniously combines outdoor air and return air, before conditioning, through dedicated compartments separated by a strategically positioned baffle. The baffle facilitates efficient blending of the air streams, resulting in optimal temperature and humidity levels for conditioning. The size of the mixing chamber is determined by prescribed ventilation rates outlined in building codes and standards [7].



**Figure 2.** Mix chamber used in the air handling unit.

- b. *Filters*: Filters are vital in AHUs for upholding indoor air quality, with several types available based on efficiency and application. Pre-filters capture larger contaminants, while HEPA filters eliminate tiny particles like bacteria and viruses. Activated carbon filters address chemicals and odors. Regular maintenance, including cleaning or replacement, ensures their efficacy in removing impurities. Filter change frequency depends on factors such as type of external pollutants, and desired air quality standards. Figure 3 illustrates diverse filter types utilized in AHUs for specific scenarios [8].



**Figure 3.** A types of filters used in air handling units.

- c. *Heat Exchanger:* Figure 4 depicts the Plate heat exchanger used in the Air Handling Unit (AHU). This type of heat exchanger consists of metal plates with fluid channels, allowing for efficient heat transfer between air streams. The plate heat exchanger enables the extraction of heat from the exiting air, thereby preconditioning the incoming air and enhancing energy efficiency in the AHU. Figure 5 highlights the Coil heat exchanger utilized in the Air Handling Unit. This heat exchanger employs coils to facilitate heat transfer through their walls. As the air streams flow in opposite directions, heat is exchanged between them. The coil heat exchanger plays a crucial role in optimizing the temperature conditions of the air streams, contributing to the overall efficiency of the AHU system [9].

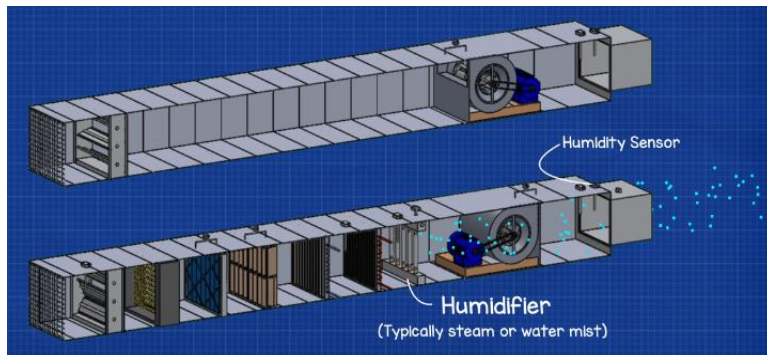


**Figure 4.** Plate heat exchanger used in Air handling unit.



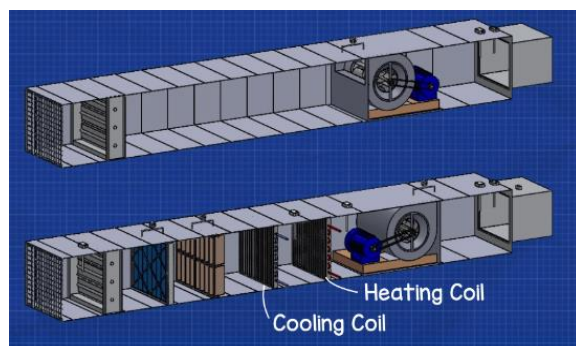
**Figure 5.** Coil heat exchanger used in Air Handling Unit.

- d. *Humidifiers/ Dehumidifiers:* Air handling units (AHUs) utilize both humidifiers and dehumidifiers to regulate air moisture levels, ensuring a comfortable and healthy indoor environment. Humidifiers add moisture using a water reservoir, humidifier pad, and fan during dry periods, while dehumidifiers remove excess moisture through a fan, drain, and cooling coil. The integration of these devices in AHUs enables optimal humidity control, enhancing indoor air quality. Figure 6, sourced from the Engineering Mindset website, illustrates a typical humidifier used in AHUs [10].



**Figure 6.** Showcases a humidifier employed in a typical AHU, sourced from <https://theengineeringmindset>

- e. *Cooling coil and Heating coil:* Cooling and heating coils are essential components within an AHU, responsible for conditioning the airflow. Cooling coils are used during hot seasons to extract heat from the air, utilizing refrigerant fluid to transfer the heat from the air to the refrigerant. The refrigerant carries the heat away from the coil, ensuring a cool indoor environment. Conversely, heating coils are employed in colder periods to warm the air. These coils transfer heat to the cold air by utilizing steam or hot water, raising the air temperature before it is distributed throughout the building. The integration of both cooling and heating coils enables the AHU to maintain optimal thermal conditions for comfort and climate control. Figure 7 showcases the heating and cooling coil used in typical AHUs, with the image sourced from the Engineering Mindset website [11].



**Figure 7.** Displays the heating and cooling coil utilized in typical AHUs, sourced from <https://theengineeringmindset.com>.

- f. *Fans:* Fans are used by air handling units (AHUs) to circulate conditioned air throughout a building. In AHUs, a variety of various fan types can be utilized, each with unique benefits and drawbacks. The following are some of the most typical fan designs found in AHUs:
- a. *Centrifugal fans:* These fans provide a high-velocity airflow using a rotating impeller. Because they can handle enormous volumes of air and are reasonably energy-efficient, centrifugal fans are frequently employed in AHUs. They can be utilized in various airflow applications and are also relatively quiet.

- b. *Axial fans*: These fans provide low-pressure airflow by mounting several blades on a hub. AHUs frequently employ axial fans because of their large airflow capacity and low noise output. They can be employed in a variety of applications and are also generally energy efficient.
- c. *Mixed-flow fans*: These fans combine the advantages of both centrifugal and axial fans to produce an energy-efficient, high-flow, high-pressure airflow. In AHUs when a large volume of air needs to be transported over a long distance, mixed-flow fans are frequently used [12].
- d. *Plenum fans*: These fans are made to be mounted directly into an AHU's plenum, producing a small and effective airflow. Plenum fans are frequently utilized in compact AHUs or AHUs with restricted rooms.

## RESULTS

The implementation of EC axial fans in the AHUs led to an observed reduction in energy consumption between 20% and 50%. The EC fans achieved an efficiency rating of over 85%, with further benefits including lower noise levels and reduced maintenance requirements. The machine learning-based control system effectively regulated air temperature and humidity in the clean rooms, addressing issues of overcooling and underheating common in traditional AHU setups. The findings indicate that EC axial fans are a viable solution for enhancing the energy efficiency of HVAC systems in manufacturing facilities. By enabling the utilization of both static and dynamic pressures, these fans outperform traditional centrifugal and plug fans, which typically waste dynamic pressure. The integration of a decision tree classification model further optimized airflow regulation, ensuring that the clean rooms maintained optimal conditions with minimal energy wastage.

The broader implications of this study support the adoption of advanced AHU designs and intelligent control systems in industrial HVAC setups. As energy efficiency becomes increasingly important, these innovations provide a pathway toward sustainable manufacturing practices that reduce energy costs and carbon emissions.

## CONCLUSION

The research successfully demonstrates that the adoption of electronically commutated axial fans and machine learning-based control in Air Handling Units can significantly improve energy efficiency and operational performance in industrial HVAC systems. The EC fans offer substantial energy savings while reducing operating costs and carbon emissions, making them an optimal choice for energy-intensive environments. Integrating a classification algorithm enables precise control over airflow, ensuring that the clean rooms maintain optimal conditions with minimal energy wastage. This study's outcomes highlight the importance of innovative AHU design and intelligent control in promoting sustainability in industrial applications, offering a viable pathway toward reduced energy consumption and environmental impact.

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