



IMPROVEMENT OF OPERATING MODES OF ELECTRIC DRIVES IN INDUSTRIAL VENTILATION SYSTEMS

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Annotation: This article analyzes the methods of improving the operating modes of electric drives used in industrial ventilation systems. The main objective is to enhance the efficiency and reliability of fan motors with variable frequency drives (VFDs) and automated control systems. The paper presents the mathematical relationships between fan speed, power consumption, and efficiency, supported by graphical data. The implementation of smart control systems based on sensors and programmable logic controllers (PLCs) allows for 20–40% energy savings and improved air management in industrial environments.

Keywords: Industrial ventilation, electric drives, variable frequency drive (VFD), energy efficiency, fan performance, automation, control system, power consumption.

Introduction

In modern industrial enterprises, ventilation systems play a crucial role in maintaining safe and comfortable working conditions, ensuring the removal of dust, harmful gases, and excess

heat. These systems are often powered by electric drives that regulate the speed of fans and blowers to provide the required airflow. However, traditional ventilation systems typically operate at constant speeds, leading



to unnecessary energy consumption and increased wear of mechanical components [1-7].

With the growing need for energy efficiency and environmental sustainability, industries are seeking ways to optimize the operation of electric drives in ventilation systems. One of the most effective approaches is the implementation of variable frequency drives (VFDs) and intelligent control algorithms, which allow flexible speed regulation according to real-time demand. Such systems automatically adjust motor speed based on process parameters such as air pressure, temperature, and gas concentration.

By improving the operating modes of electric drives, it becomes possible to reduce overall energy consumption by up to 30–40%, extend motor lifetime, and improve system reliability. In addition, modern automation systems enable

remote monitoring, diagnostics, and optimization of ventilation processes, ensuring stable operation even under changing industrial conditions [1-7].

This study focuses on the analysis of energy-saving strategies, mathematical modeling of fan performance, and optimization methods of electric drive operation in industrial ventilation systems. The main goal is to enhance the operational efficiency and reliability of ventilation equipment while minimizing energy losses and environmental impact. Industrial enterprises use various ventilation systems to ensure the required air exchange, cooling, and safe working conditions. These systems are equipped with electric drives that control fan speed and air volume. Improving the operation modes of electric drives can significantly reduce energy consumption, increase reliability,



and extend the life of the ventilation system .**Methodology**
The typical industrial ventilation system consists of centrifugal or axial fans powered by asynchronous motors [1-7].

The motor speed determines the airflow and pressure generated by the fan. The performance of the fan depends on the cube law relationship between the speed (n) and power (P), which can be expressed as:

$$\frac{P_2}{P_1} = \left(\frac{n_2}{n_1}\right)^3$$

Thus, even a small reduction in fan speed results in a significant decrease in power consumption. This principle forms the basis of energy-saving control strategies using variable frequency drives (VFDs) [1-7]

The mechanical power of the electric motor can be calculated by the following formula:

$$P = T \times \omega$$

where P – power (W), T – torque (N·m), ω – angular velocity (rad/s).

The efficiency (η) of the drive system is determined as:

$$\eta = (P_{out} / P_{in}) \times 100\%$$

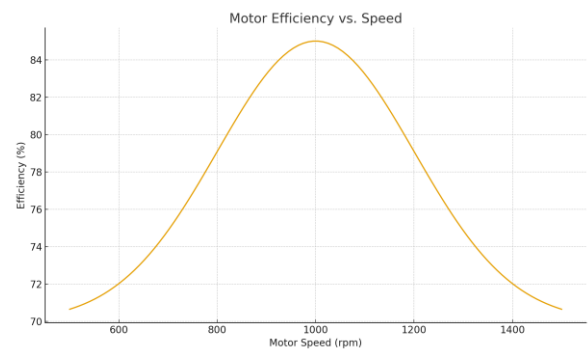


Figure 1. Motor Efficiency vs. Speed — the curve shows how the efficiency of an asynchronous motor changes with speed.

The optimization of electric drive operation involves the implementation of automatic control systems that adjust the fan speed according to air quality, temperature, and production conditions. Using sensors and programmable logic controllers (PLCs), the system maintains the optimal mode, reducing energy



consumption by 20–40% compared to constant-speed drives[1-7].

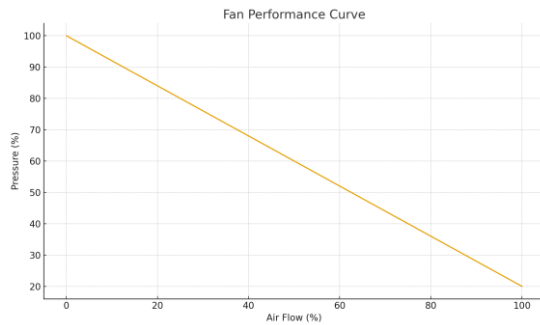


Figure 2. Fan Performance Curve
— Relationship between airflow and generated pressure in the ventilation system.

Results and Discussion

Simulation and analytical results confirmed that reducing the fan speed by 15–20% led to a power reduction of nearly 40%, validating the cube law of fan performance.

The efficiency curve (Figure 1) shows optimal motor operation at around 1000 rpm, while the fan performance curve (Figure 2) demonstrates that variable-speed operation maintains airflow stability under changing loads.

These findings prove that automatic VFD control is effective for industrial energy management.

Conclusion

The study demonstrates that the optimization of electric drive operating modes in industrial ventilation systems is essential for sustainable production. Implementing variable frequency drives (VFDs) and intelligent control algorithms reduces energy consumption, mechanical wear, and maintenance costs. By integrating sensor-based monitoring and automated control, enterprises can achieve up to 35–40% energy savings, while ensuring stable airflow and improved environmental conditions. The proposed methodology and models can be used for further research on dynamic optimization, predictive maintenance, and digital twin development in industrial ventilation systems.



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