

FREQUENCY CONTROL OF MECHATRON MODULAR DRIVES

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Abstract: Asynchronous motors, commonly known as induction motors, are critical components in modern industrial applications due to their simplicity, robustness, and efficiency. This article provides an in-depth exploration of asynchronous motors, their types, operational principles, and the innovative application of regenerative braking. Regenerative braking in asynchronous motors offers significant energy savings and efficiency improvements, particularly in electric vehicles and industrial systems. This process converts the kinetic energy of a system back into electrical energy during braking, which can then be fed back into the power supply or stored. This article discusses the mechanics of regenerative braking, its benefits, and the role of variable frequency drives (VFDs) in controlling this process.

Keywords: Asynchronous Motors, Induction Motors, Frequency Converters, Variable Frequency Drives (VFDs), Inverters

ЧАСТОТНОЕ УПРАВЛЕНИЕ МЕХАТРОННЫМИ МОДУЛЬНЫМИ ПРИВОДАМИ

Аннотация: Асинхронные двигатели, широко известные как асинхронные двигатели, являются важнейшими компонентами современных промышленных применений благодаря своей простоте, надежности и эффективности. В этой статье представлено углубленное исследование асинхронных двигателей, их типов, принципов работы и инновационного применения рекуперативного торможения. Регенеративное торможение в асинхронных двигателях обеспечивает значительную экономию энергии и повышение эффективности, особенно в электромобилях и промышленных системах. Этот процесс преобразует кинетическую энергию системы обратно в электрическую энергию во время торможения, которую затем можно передать обратно в источник питания или сохранить. В этой статье обсуждается механика рекуперативного торможения, его преимущества и роль преобразователей частоты (ЧРП) в управлении этим процессом.

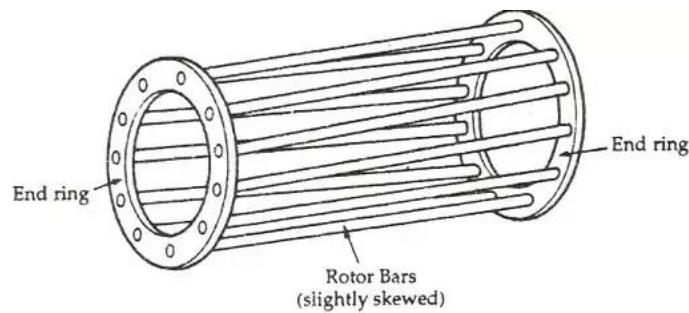
Ключевые слова: асинхронные двигатели, асинхронные двигатели, преобразователи частоты, частотно-регулируемые приводы (ЧРП), инверторы.

INTRODUCTION

Asynchronous motors, or induction motors, are a type of alternating current (AC) electric motor where the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. Unlike synchronous motors, asynchronous motors do not require an external commutator or electrical connections to the rotor, which simplifies their design and enhances their reliability.

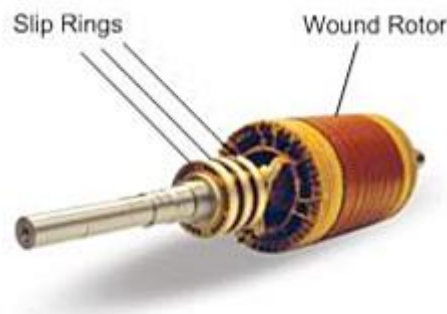
Types of Asynchronous Motors. There are two primary types of rotors used in asynchronous motors:

- **Squirrel-Cage Rotor:** A squirrel-cage rotor is the rotating part of the common squirrel-cage induction motor (see pic.1). This is the most common type due to its simplicity and robustness. It consists of a cylinder of steel laminations, with aluminum or copper conductors embedded in its surface.



Pic. 1 - Squirrel-Cage Rotor

● **Wound Rotor:** This type has windings on the rotor that are connected to external resistances via slip rings (see pic.2), allowing for better control of the motor's speed and torque characteristics.



Pic. 2 - Wound Rotor

Operational Principles. The operation of an asynchronous motor is based on the principle that when a three-phase voltage is applied to the stator winding, it creates a rotating magnetic field. This field induces an electromotive force (EMF) in the rotor, causing current to flow if the rotor circuit is closed. The interaction between the magnetic fields of the stator and the rotor creates a torque that makes the rotor turn.

The speed of the rotor (n) in an asynchronous motor is not equal to the speed of the rotating magnetic field (n_s). The difference between these speeds is called slip (s), which is necessary for torque production. The slip is usually expressed as a percentage and is given by the formula [1]:

$$S = \frac{n_s - n}{n_s} \times 100\% \quad [1]$$

Applications and Speed Control. Asynchronous motors are widely used in industrial drives, fans, pumps, and compressors. Traditionally used for constant-speed service, they are increasingly utilized in variable-speed applications with the help of VFDs. VFDs allow for precise speed control by adjusting the frequency and voltage supplied to the motor, making them suitable for applications where speed variation is necessary for process control or energy savings.

Regenerative Braking in Asynchronous Motors. Regenerative braking is a process where the motor operates as a generator during braking, converting the kinetic energy of the system back into electrical energy. This energy can be fed back into the power supply or stored for later use.

Mechanics of Regenerative Braking.

Speed Exceeds Synchronous Speed: For regenerative braking to occur, the motor's speed must exceed the synchronous speed of the stator's rotating magnetic field. This can happen when the load drives the motor, such as when a vehicle is going downhill.

Motor Acts as Generator: Once the rotor speed surpasses the synchronous speed, the slip becomes negative, and the motor starts to act as a generator. The direction of power flow reverses from the rotor to the stator.

Energy Recovery: The electrical energy generated by the motor (now acting as a generator) is sent back to the power grid or stored in a battery or capacitor bank. This process is efficient and can lead to significant energy savings.

Control by Variable Frequency Drives. VFDs or inverters are typically used to control the regenerative braking process. They adjust the frequency and voltage supplied to the motor to manage the braking force and the amount of energy recovered. VFDs enable precise control, enhancing the efficiency and effectiveness of regenerative braking.

Benefits of Regenerative Braking. Regenerative braking is particularly beneficial in electric vehicles and hybrid systems, where it can significantly improve energy efficiency and extend the range of the vehicle. It also reduces wear on mechanical braking components, leading to lower maintenance costs. Additionally, it contributes to energy savings in industrial applications by converting excess kinetic energy back into usable electrical energy.

CONCLUSION

In conclusion, let us have a look at some points about the frequency control of mechatron modular drives:

- asynchronous motors and regenerative braking represent pivotal advancements in electrical engineering, with profound implications for industrial and transportation sectors. The versatility and efficiency of asynchronous motors make them indispensable in a wide range of applications, from industrial machinery to HVAC systems. The integration of regenerative braking not only enhances the energy efficiency of these motors but also contributes to sustainability efforts by converting kinetic energy into usable electrical power.
- The adoption of variable frequency drives (VFDs) further enhances the performance and control of asynchronous motors, allowing for precise speed regulation and energy optimization. In the context of electric vehicles, regenerative braking offers significant benefits, including extended range, reduced emissions, and lower operating costs.
- Ongoing research and development efforts are poised to unlock new possibilities in asynchronous motor technology and regenerative braking systems. Innovations in materials, design, and control algorithms promise to further improve efficiency, reliability, and sustainability, driving continued progress towards a greener and more efficient future.
- Asynchronous motors and regenerative braking stand as testament to the ingenuity and innovation of the engineering community, offering solutions to pressing challenges in energy efficiency, environmental sustainability, and industrial automation. By harnessing the power of electromagnetism and advanced control systems, these technologies pave the way for a brighter, more sustainable tomorrow.

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