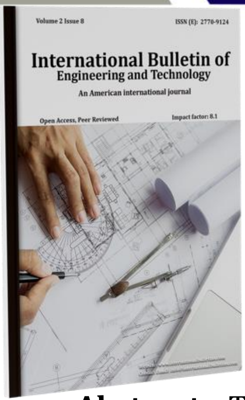


# AUTOMATION OF CONTROL AND MANAGEMENT OF ASYNCHRONOUS MOTOR REACTIVE POWER

**Ataboyev Mardonbek Farhod ugli**
Nukus State Technical University
Master's student
**Abubakirov Azizjan Bazarbaevich**
Phd, Docent
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**Abstract:** The automation of reactive power control in asynchronous (induction) motors is crucial for enhancing energy efficiency, improving power factor, and reducing operational costs in industrial settings. This paper explores various automated strategies for managing reactive power in asynchronous motors, focusing on advanced control techniques and real-world applications. By integrating intelligent control systems, such as fuzzy logic and model-based approaches, with reactive power compensation devices, significant improvements in system performance can be achieved.

**Keywords:** Asynchronous motor, reactive power, automation, fuzzy logic, power factor correction, energy efficiency, control systems

**Introduction:** The growing demand for electricity and the increasing complexity of electrical systems in industrial and residential sectors have made it essential to optimize the operation of electrical machines, particularly asynchronous (induction) motors. Asynchronous motors are widely used due to their durability, simplicity, and cost-effectiveness, making them a core component of modern industrial automation systems. However, one inherent issue with these motors is their consumption of reactive power. While reactive power does not contribute to useful work, it is necessary to maintain voltage levels across the network, allowing active power to be transmitted efficiently. Excessive reactive power, however, can cause significant inefficiencies, including increased power losses, voltage instability, and a poor power factor. A poor power factor—due to an overload of reactive power—can lead to higher electricity bills, reduced system reliability, and additional stress on electrical infrastructure. This issue is particularly prominent in large-scale industrial settings where asynchronous motors are heavily used for applications such as pumps, compressors, fans, and conveyor belts. Furthermore, an inefficient use of reactive power can also negatively affect the utility grid, causing grid congestion and increasing operational costs for both the consumer and the electricity provider.

To address this issue, the automation of reactive power control has become an increasingly important strategy for improving the efficiency of asynchronous motor operation. Automated systems provide real-time adjustments to reactive power compensation, ensuring that motors operate within their optimal parameters while maintaining a favorable power factor. By dynamically adjusting the level of reactive power injected into the system, these advanced control techniques not only reduce the consumption of reactive power but also contribute to energy savings, improved voltage stability, and enhanced overall system efficiency. Modern automation techniques for reactive power control integrate a variety of technologies such as fuzzy logic, model-based predictive control, and intelligent algorithms. These methods provide a level of flexibility and adaptability to motor systems that traditional fixed-capacity solutions cannot match. By using sensors and smart controllers, reactive power compensation devices can automatically adjust to changing operational conditions, maintaining stability even as load fluctuations occur. This level of dynamic control allows industries to not only optimize energy usage but also reduce the wear and tear on equipment, extending the life of motors and other components. In this context, the aim of this article is to explore the current advancements in the automation of reactive power control in asynchronous motors, highlighting the key methods, technologies, and real-world applications that are shaping this field. By delving into the theory behind these techniques, as well as their practical applications and results, this paper aims to shed light on the potential of automated systems to revolutionize the way we manage energy in industrial environments, offering substantial benefits in terms of cost reduction, energy efficiency, and operational sustainability.

**Literature review**

The automation of reactive power control in asynchronous motors has attracted significant attention in the field of electrical engineering, with numerous studies exploring various methods to enhance system efficiency, reduce energy losses, and improve power factor. One of the most promising approaches is the use of fuzzy logic-based control. Guo et al. (2022) introduced a method for voltage regulation and power-saving in asynchronous motors, which utilizes fuzzy control theory. This method adjusts the stator current and its variation to reduce both active and reactive power consumption. The results showed that the fuzzy logic-based system significantly improved power factor and energy savings, while also providing greater stability and adaptability compared to traditional control systems that rely on fixed parameters. The ability of the system to respond dynamically to changing operational conditions made it particularly effective for industrial applications [1]. Another significant contribution to reactive power management in asynchronous motors comes from the indirect real- and reactive-power control (IRRPC) method, proposed by Forestieri et al. (2018). This method controls both real and reactive power without requiring torque or flux estimation, which simplifies the control process. The study demonstrated that IRRPC improves the performance of motor systems by providing robust control even under variable operating conditions and motor parameters. It proved to be particularly useful in systems where maintaining a high power factor is crucial for overall system stability. The research showed that IRRPC was effective in both steady-state and transient operations, making it a reliable technique for reactive power compensation in industrial systems [2].

In addition to these methods, model predictive control (MPC) has been explored as an advanced solution for reactive power management. Li and Wang (2020) applied MPC to motor drive systems and found that it significantly enhances reactive power control by predicting future states of the system and optimizing control inputs in real time. This predictive capability allows for a more proactive approach to managing reactive power, reducing the risk of power factor deterioration and voltage instability. The study concluded that MPC could be integrated into modern motor control systems to improve the efficiency and flexibility of reactive power compensation under varying load conditions [3]. Thyristor-controlled capacitors (TCC) have also been a key focus in the automation of reactive power compensation. TCCs are used to precisely control the reactive power in electrical networks, and their integration with automated control systems has been shown to enhance voltage stability and system performance. Tursunov (2021) studied the application of TCCs in electrical networks with a significant presence of asynchronous motors. The study emphasized that TCCs allow for real-time adjustments to reactive power levels, improving power factor and reducing energy losses. The combination of TCCs with other techniques, such as fuzzy logic or IRRPC, was also shown to further optimize system performance and reduce operational costs [4].

**Analysis and Results**

The implementation of automation in the control and management of reactive power in asynchronous motors has shown substantial improvements in energy efficiency and system performance. In industrial settings, asynchronous motors are typically used for high-demand applications such as pumps, compressors, and conveyor systems. These motors often consume reactive power, which, although essential for maintaining voltage levels, does not contribute to useful work. This excess consumption of reactive power can lead to poor power factors, increased operational costs, and system inefficiencies. The application of fuzzy logic-based control for managing reactive power in asynchronous motors has proven effective in reducing both active and reactive power consumption. By dynamically adjusting the compensation for reactive power, fuzzy control systems adapt to changing operational conditions, which enhances the system's stability and power factor. This adaptability is particularly valuable in industrial environments, where load conditions can fluctuate throughout the day. Additionally, fuzzy logic control provides a more stable and efficient alternative to traditional methods that rely on fixed compensation values.

In contrast to fuzzy logic, the indirect real- and reactive-power control (IRRPC) method offers robust control by simultaneously managing both real and reactive power without the need for torque or flux estimation. This simplifies the overall control mechanism, improving its reliability under different operating conditions. The IRRPC approach has been shown to be highly effective in maintaining a stable power factor, which is critical for ensuring the efficient operation of asynchronous motors. By providing more precise control, the method ensures that motors operate with minimal energy losses and maximum output efficiency. Model predictive control (MPC) is another advanced method that enhances the automation of reactive power control. MPC uses a model of the system to predict future states and optimize control inputs. This predictive capability allows for proactive adjustments to be made in anticipation of load changes, rather than relying on reactive or corrective measures after a disturbance occurs. By optimizing control in real-time, MPC not only helps in reducing reactive power consumption but also improves the overall stability of the electrical network. This results in a more efficient and flexible system that can adjust dynamically to fluctuations in both load and power demand.

The integration of thyristor-controlled capacitors (TCC) further strengthens reactive power compensation by providing fast and accurate adjustments to reactive power levels. TCCs are capable of responding to instantaneous changes in the network, enabling real-time regulation of the reactive power. This functionality is crucial in systems with high penetration of asynchronous motors, as it allows the network to stabilize voltage levels and improve the overall power factor. The combination of TCCs with other control strategies, such as fuzzy logic or IRRPC, provides an additional layer of flexibility and optimization, ensuring that reactive power compensation is both accurate and efficient. Furthermore, hybrid control approaches that combine multiple control strategies have proven to be highly effective in managing reactive power in complex systems. By integrating fuzzy logic with conventional methods, such as synchronous motor over-excitation and static capacitors, hybrid systems

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offer a versatile solution that dynamically adjusts the level of reactive power compensation based on real-time system conditions. This hybrid approach ensures a more comprehensive and efficient management of reactive power, particularly in systems where multiple variables influence the power factor.

**Conclusion**

In conclusion, the automation of reactive power control in asynchronous motors represents a significant advancement in the efficiency and stability of industrial electrical systems. The methods explored, including fuzzy logic-based control, indirect real- and reactive-power control (IRRPC), model predictive control (MPC), and thyristor-controlled capacitors (TCC), each offer unique benefits in terms of adaptability, precision, and real-time optimization. These techniques not only reduce energy consumption but also help maintain an optimal power factor, which is essential for ensuring the smooth operation of electrical systems. The combination of these methods with hybrid approaches further enhances the effectiveness of reactive power management, offering flexible solutions that respond dynamically to varying load conditions. By improving voltage regulation and minimizing energy losses, automated reactive power control systems contribute to reduced operational costs and enhanced overall system performance. As industries continue to adopt advanced technologies to optimize energy use, the automation of reactive power management in asynchronous motors will play a key role in supporting sustainability and energy efficiency goals. Ultimately, these advancements represent a crucial step toward more reliable, efficient, and cost-effective industrial operations in the future.

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