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Specific features of power supply in agro-industrial complex enterprises and achieving energy efficiency

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Abstract. Agricultural products occupy a significant place among the goods forming the foundation of the economy of the Republic of Uzbekistan. Therefore, agro-industrial complex enterprises (AICEs) play a crucial role in the process of primary processing of agricultural raw materials into import-substituting and export-oriented finished products. Due to the high market demand for finished products and the incentives provided by the state, the number of AICEs has increased significantly in recent years. The expansion of production capacities has consequently led to a substantial increase in overall electricity consumption within these enterprises. This article analyzes electricity consumption patterns in agro-industrial complex enterprises based on their specific operational characteristics.

INTRODUCTION

Agricultural products occupy a significant place among the goods forming the foundation of the economy of the Republic of Uzbekistan. Therefore, agro-industrial complex enterprises (AICEs) play a crucial role in the process of primary processing of agricultural raw materials into import-substituting and export-oriented finished products. Due to the high market demand for finished products and the incentives provided by the state, the number of AICEs has increased significantly in recent years. The expansion of production capacities has consequently led to a substantial increase in overall electricity consumption within these enterprises. This article analyzes electricity consumption patterns in agro-industrial complex enterprises based on their specific operational characteristics.

EXPERIMENTAL RESEARCH

Since agricultural products mature at different times and their storage and processing require diverse technological processes, agro-industrial complex enterprises cannot be classified as a single homogeneous group. International practice identifies and analyzes AICE technological processes according to the following key characteristics:

Seasonality. Agricultural production is inherently seasonal. This requires precise coordination of planting and harvesting operations with the operating periods of agro-industrial enterprises, as well as careful planning of production cycles.

Process integration. AICEs demonstrate a high degree of integration across all production stages, from crop cultivation and livestock farming to product processing and storage. This integration enables effective management and quality control at each stage.

Dependence on climatic conditions. The operation of AICEs is strongly dependent on soil and climatic conditions. Climate change can lead to increased incidence of diseases in crops and livestock, resulting in reduced yields. A shortage of primary raw materials consequently causes a decline in industrial output.

Quality requirements. Regulatory authorities and consumers impose strict requirements on product safety and quality. This necessitates the implementation of modern technologies that comply with established standards.

Interaction with living organisms. The involvement of living organisms such as plants and animals introduces biological factors that are difficult to predict, requiring adaptive and flexible production management.

Mechanization and automation. To improve efficiency and reduce labor costs, modern mechanized and automated technologies are widely implemented in AICEs. Examples include tractors, harvesters, drip irrigation systems, and other specialized equipment.

Environmental and energy resources. Consideration of energy consumption and environmental impact is essential. The implementation of energy-saving technologies and sustainable production methods is becoming increasingly relevant.

Logistics and supply chains. Efficient delivery of products from fields to processing facilities and then to end consumers with minimal costs is critical. High logistics costs increase production costs and reduce market competitiveness.

Scientific research and innovation. Continuous research and the introduction of innovative solutions in agronomy, livestock production, and processing technologies enhance resistance to pests and diseases, increase productivity, and improve product quality.

The diversity of these technological processes directly affects electricity consumption levels in agro-industrial enterprises [1]. Accordingly, AICEs can be classified by electricity consumption characteristics as follows:

High energy-consuming enterprises. Facilities requiring significant energy for processing, storage under controlled conditions, irrigation (including pumping stations and drip irrigation systems widely used in Uzbekistan), and mechanized operations.

Seasonal and cycle-dependent enterprises. Enterprises whose energy consumption varies depending on the season and stages of the production cycle, with peak consumption during harvesting and processing periods.

Diverse energy sources. Enterprises that utilize various energy sources, including electricity, diesel fuel, natural gas, biomass, and renewable energy. In some cases, agricultural waste is used for biogas production.

Energy-efficient enterprises. Enterprises that minimize environmental impact and reduce total energy consumption through advanced technologies and optimized production processes.

Enterprises with autonomous energy sources. Agro-industrial facilities, particularly in remote or hard-to-reach areas, that rely on autonomous power sources such as photovoltaic systems or diesel generators to ensure uninterrupted operation.

Monitoring and control systems. The implementation of automated control systems (ACS) enables effective energy management, loss detection, and optimization of energy consumption.

Environmental impact considerations. Compliance with environmental standards through the adoption of “green” technologies and energy-efficient solutions reduces waste and environmental harm.

Energy storage systems. Energy storage devices are required to ensure continuity of production during peak demand periods or power supply disruptions.

Market dependency. Electricity prices may fluctuate significantly due to market conditions and geopolitical factors, affecting operational costs and requiring flexible energy planning.

RESEARCH RESULTS

Energy Efficiency and Reliability in Rural Power Networks. The energy efficiency and reliability of agro-industrial complexes are critical components of modern rural electrical infrastructure. Reducing electricity losses, improving supply reliability, and maintaining power quality remain key challenges in the energy sector. To address these issues, new methods and technologies are being introduced, and scientific solutions are being developed to enhance network performance, reliability, and power quality.

This article focuses on developing strategies to reduce energy losses in rural power networks, improve power supply reliability, and maintain electricity quality within regulatory limits.

Key priorities include increasing the efficiency of electricity generation and distribution, ensuring regular technical maintenance, optimizing voltage levels, and installing reactive power compensation devices.

Another essential direction involves improving power supply reliability through the implementation of backup systems, intelligent technologies, and balanced load distribution, thereby extending system operational continuity.

To improve power quality indicators, the use of harmonic filters, voltage regulators, and uninterruptible power supply (UPS) systems is recommended to protect sensitive equipment and mitigate power quality disturbances.

Reactive Power Compensation in Agro-Industrial Enterprises. Based on existing legislation and regulatory decisions, the issue of reactive power control has been actively addressed in recent years across all legal consumer nodes. This has already produced significant positive effects throughout the national power system of Uzbekistan. Notably, one of the most efficient and rapid methods for improving energy efficiency in agro-industrial complexes is the installation of reactive power control systems.

Analysis of scientific research confirms that energy consumption in AICEs is non-uniform and requires specific reactive power control methods. One such method is load-current-based regulation (Figure 1), where reactive power compensation is controlled according to the load current at the consumer node.

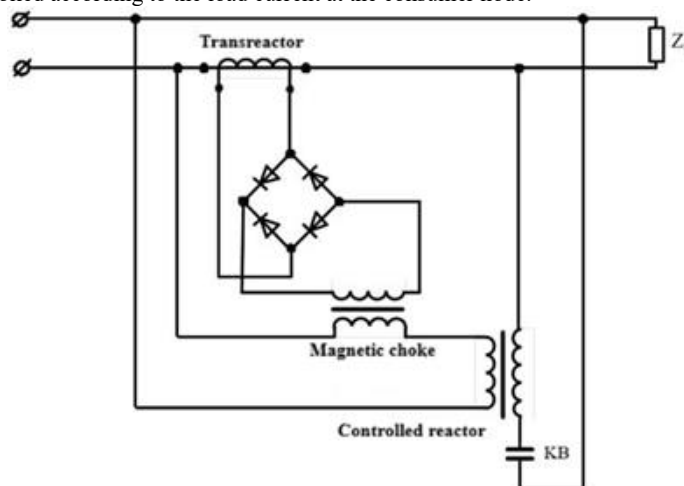


FIGURE 1. Automatic control scheme based on load current function

The scheme includes the following elements:

Diode bridge – Converts alternating current into direct current.

Transreactor – A combined transformer-reactor unit with a non-ferromagnetic magnetic core; its primary winding is connected in series with the network, similar to a current transformer.

Static capacitor banks – Electrical devices used to generate reactive power.

Magnetic choke – A static electromagnetic device used as an inductive reactance; includes AC chokes, rectifier filter chokes, and saturable reactors.

Controlled reactor – Used in conjunction with an automatic control system for smooth regulation of electrical network parameters.

Reactive power compensation using this method improves network efficiency and stability and contributes to solving key energy sector challenges.

CONCLUSIONS

The analyzed characteristics highlight the importance of a comprehensive approach to energy resource management in agro-industrial enterprises, including the implementation of innovative technologies and strategies to enhance efficiency and sustainability. Recommended measures include:

1. Detailed analysis of AICE production processes;
2. Timely and high-quality energy audits to identify loss points;
3. Modernization of low-efficiency electrical equipment;
4. Expansion of theoretical and practical energy-saving measures;
5. Strengthening cooperation with higher education institutions to implement scientific and innovative solutions.

Energy audits reveal insufficient deployment of automatic reactive power compensation systems in agro-industrial enterprises [3]. Under these conditions, widespread promotion and implementation of such systems represent an effective practical measure for achieving energy savings and improving overall energy efficiency.

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