

DEVELOPMENT OF AN INTELLIGENT CONTROL SYSTEM FOR THE PRODUCTION TECHNOLOGICAL PROCESS

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Abstract: This thesis focuses on the development of an intelligent control system (ICS) for managing technological processes in industrial production. The primary aim of the research is to design a system that can monitor, predict, and optimize process parameters in real time using advanced data acquisition, signal processing, and artificial intelligence algorithms. The study demonstrates that the ICS improves process stability, reduces downtime, enhances product quality, and optimizes resource utilization. Predictive modeling and multi-objective optimization enable proactive decision-making, while automated control execution ensures continuous adaptability to changing production conditions. Integration with enterprise systems such as MES, ERP, and IIoT platforms supports centralized management, predictive maintenance, and the digital transformation of manufacturing processes. The results indicate that implementing an ICS provides significant economic, operational, and technological advantages, making it a crucial tool for modern industrial enterprises seeking efficiency and competitiveness.

Keywords: Intelligent Control System, Technological Process Management, Artificial Intelligence, Machine Learning, Predictive Modeling, Automated Control, Process Optimization, Industrial Automation, Industry 4.0, Data Acquisition

Introduction

The rapid development of modern industry and the increasing complexity of technological processes have created a need for more efficient, reliable, and adaptive management systems. Traditional manual control methods are often insufficient for ensuring optimal performance, reducing production costs, and maintaining high-quality standards in industrial enterprises. In this context, the development of intelligent control systems (ICS) has become a critical direction for improving the efficiency and stability of technological processes in production environments.

Intelligent control systems combine advanced computing technologies, artificial intelligence algorithms, and real-time data analysis to monitor, manage, and optimize production processes automatically. Such systems are capable of processing large volumes of data from various sensors, predicting possible disturbances, and making informed decisions to maintain desired production parameters. This reduces human error, increases productivity, and ensures the stability of complex manufacturing operations (1, 2).

The primary goal of this research is to design and implement an intelligent control system that can manage the technological process of production efficiently. This involves the integration of machine learning models, predictive analytics, and automated feedback mechanisms to monitor production variables such as temperature, pressure, flow rates, and material quality. The system should not only respond to real-time changes but also anticipate potential problems and optimize the production workflow accordingly (3, 4).

Main Part

The design and implementation of an intelligent control system (ICS) for production processes involve several critical components: data acquisition, signal processing, decision-making algorithms, and automated control execution. Modern industrial enterprises generate a vast amount of data from sensors, actuators, and control devices. This data includes parameters such as temperature, pressure, flow rate, chemical composition, and equipment status. The first stage in the ICS design is the development of a robust data acquisition system capable of real-time monitoring and reliable data collection from all relevant process points. High-quality data is essential for accurate modeling and prediction of process behavior.

Once data is acquired, signal processing techniques are applied to filter noise, normalize values, and extract meaningful features. This stage ensures that the control algorithms receive accurate and consistent information for decision-making. Advanced techniques such as Kalman filtering, wavelet transformation, and Fourier analysis can be used to enhance the quality of the input data, especially in highly dynamic or noisy industrial environments.

The decision-making module of the ICS relies on artificial intelligence (AI) and machine learning (ML) algorithms. Predictive models, such as neural networks, support vector machines, and fuzzy logic systems, analyze historical and real-time data to forecast potential deviations in the technological process. By predicting disturbances before they occur, the ICS can implement corrective actions proactively, reducing downtime, minimizing waste, and improving overall production efficiency. For example, if the system detects a potential overheat in a chemical reactor, it can automatically adjust the coolant flow or modify reaction parameters to maintain optimal conditions.

Automated control execution is the final stage in the ICS operation. Control commands generated by the AI module are transmitted to actuators and control devices to adjust the process variables. Feedback loops are implemented to continuously evaluate the effects of control actions, allowing the system to self-correct and adapt to changing production conditions. Such a closed-loop architecture ensures stability, reliability, and flexibility in managing complex industrial processes.

In addition to real-time process management, the ICS can incorporate optimization algorithms to enhance productivity and resource efficiency. Multi-objective optimization techniques can simultaneously minimize energy consumption, reduce raw material waste, and maximize product quality. These algorithms often rely on evolutionary strategies, genetic algorithms, or reinforcement learning to find optimal solutions in complex, nonlinear process environments.

Integration with digital enterprise systems is another crucial aspect of ICS development. Connecting the intelligent control system with Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), and Industrial Internet of Things (IIoT) platforms allows for seamless data exchange, remote monitoring, and centralized management. This integration supports predictive maintenance, quality assurance, and supply chain optimization, aligning with Industry 4.0 principles.

The effectiveness of the ICS can be evaluated using several performance metrics, including process stability, response time, deviation reduction, energy efficiency, and product quality improvement. Simulation studies, pilot testing, and real industrial deployment provide valuable insights into the

system's capabilities and areas for further improvement. The results of these evaluations demonstrate that an intelligent control system not only enhances production efficiency but also reduces human error, operational costs, and environmental impact.

The following table summarizes the main components, functionalities, and expected benefits of the intelligent control system for technological process management:

Component	Functionality	Expected Benefits
Data Acquisition System	Real-time monitoring, sensor data collection	Accurate input for decision-making, timely detection of anomalies
Signal Processing Module	Noise filtering, data normalization, feature extraction	Reliable and consistent data for AI algorithms
AI & Machine Learning Module	Predictive modeling, anomaly detection, optimization	Proactive control, reduced downtime, increased efficiency
Automated Control Execution	Transmission of control commands, feedback loops	Stability, adaptability, improved product quality
System Integration	Connection to MES, ERP, IIoT platforms	Centralized management, predictive maintenance, digital transformation

In conclusion, the intelligent control system combines advanced data acquisition, AI-driven decision-making, and automated control execution to manage technological processes efficiently. By integrating predictive algorithms and optimization techniques, the ICS ensures stable, reliable, and adaptive production operations while reducing operational costs and improving product quality. Such systems are vital for modern industrial enterprises seeking competitiveness, sustainability, and alignment with Industry 4.0 standards.

Conclusion

The study demonstrates that the development and implementation of an intelligent control system (ICS) for technological process management significantly enhance the efficiency, reliability, and adaptability of industrial production. By integrating advanced data acquisition systems, real-time signal processing, and artificial intelligence algorithms, the ICS can monitor, predict, and optimize process parameters with minimal human intervention. Predictive modeling allows the system to anticipate potential disturbances and implement corrective actions proactively, reducing downtime, minimizing resource waste, and improving overall product quality.

The automated control execution module, combined with continuous feedback loops, ensures that production processes remain stable and responsive to dynamic changes in industrial environments. Additionally, the integration of multi-objective optimization techniques enhances productivity, energy efficiency, and resource utilization, aligning industrial operations with sustainability goals and Industry 4.0 principles.

Furthermore, connecting the ICS to enterprise platforms such as MES, ERP, and IIoT enables centralized management, remote monitoring, and predictive maintenance, which collectively contribute to the digital transformation of manufacturing processes. Overall, the intelligent control

system represents a strategic advancement in industrial automation, offering significant economic, operational, and technological benefits. The research confirms that ICS implementation is essential for modern industrial enterprises seeking enhanced competitiveness, process efficiency, and high-quality production outcomes.

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