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IMPLEMENTATION AND RESEARCH OF CYBER-PHYSICAL SYSTEMS IN AUTOMATED PRODUCTION

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The rapid development of digital technologies has significantly influenced industrial automation. Modern production demands not only high precision and efficiency but also the ability to adapt to dynamic conditions. Cyber-physical systems combine physical processes with computational algorithms, enabling flexible, intelligent, and data-driven production management. CPS are used in various sectors, including manufacturing, energy, and transportation, to ensure reliability and continuous improvement through digital twins, remote monitoring, and smart control technologies. The development of CPS contributes to the transition from traditional automation to intelligent, interconnected production systems.

Purpose and Objectives.

The purpose of this study is to design and investigate a cyber-physical control system for automated industrial processes using modern PLC-based technology. The main objectives are:

- to analyze the principles and structures of cyber-physical systems in industrial automation;

- to develop a system model using Siemens S7-1200 controller;

- to implement a PID control algorithm for temperature regulation in TIA Portal;

- to design an HMI interface for process visualization and operator control;- to perform simulation and experimental testing to evaluate system performance.

Methods and Tools. The study employs methods of mathematical modeling, system analysis, and simulation. The hardware part is represented by the Siemens S7-1200 PLC, which serves as the core control element. The software

implementation is carried out in Siemens TIA Portal, allowing the integration of logic control, PID tuning, and visualization. For monitoring and operator interaction, the WinCC Runtime Advanced environment was used to create an HMI screen displaying real-time process data. The system model was tested under various operating conditions to analyze stability, response time, and energy efficiency.

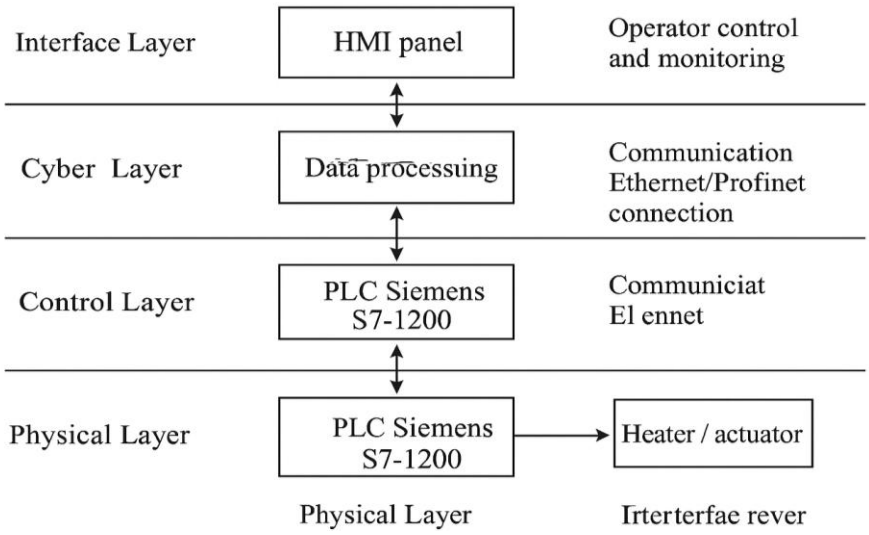

Figure 1 – Structural diagram of the cyber-physical system

Results and Discussion. The developed cyber-physical system ensures autonomous control of technological parameters, such as temperature, within predefined limits. The results demonstrate that CPS-based systems improve process stability, reduce human intervention, and enable real-time data acquisition for decision-making. The implementation of PID control in the system allows for precise adjustment of temperature with minimal overshoot and steady-state error. The HMI visualization provides clear feedback to the operator, enabling monitoring and fault detection. The study also highlights that integrating CPS technology facilitates the creation of digital twins and supports predictive maintenance strategies. By using virtual models, the performance of physical systems can be predicted and optimized before actual implementation, reducing downtime and costs.

Conclusion. The conducted research confirms that cyber-physical systems play a crucial role in the digital transformation of automated production. Their integration allows for higher efficiency, safety, and sustainability of industrial processes. The designed CPS-based control model using Siemens TIA Portal can serve as a foundation for future smart manufacturing systems. Further research may focus on expanding the system to include artificial intelligence-based optimization, data analytics, and cloud-based monitoring. Such developments will strengthen the link between the physical and virtual components of production, forming a complete Industry 4.0 ecosystem.

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