

# Application and Optimization of Automation Technology in Typical Process Flows

Xinxin Liu

School of Electrical Engineering and Automation, Henan University of Urban Construction, Pingdingshan, 467036, China

## Abstract

Automated control technology can effectively address the problems of inefficient operation and extensive control of traditional production processes, and is an important support for industrial upgrading. This article selects three mainstream production processes: food processing, metallurgy, and water treatment, analyzes the application effect of automation technology in core production processes, and summarizes cross-industry optimization strategies. Practical data shows that automation transformation can achieve precise control and coordinated operation of the entire production process: the efficiency of intelligent sorting in food processing is 3 – 5 times higher than that of manual labor, and the efficiency of packaging is increased by 25 – 30%; The numerical control (NC) rate of key processes in the metallurgical industry has exceeded 75%, and intelligent control of blast furnaces can reduce the coke ratio by about 3%; The online monitoring efficiency of water treatment has been improved by more than 4 times compared to manual methods, and intelligent dosing can increase the utilization rate of chemicals by 20%. The measures proposed in this article, such as process standardization and precise energy consumption control, can provide reference for the automation transformation of the industry and promote the development of production towards high efficiency, low carbon, and stability.

## Keywords

Automation technology; Typical process flows; Process optimization; Intelligent control; Industrial digitalization.

## 1. Introduction

Traditional process-based industrial production has long relied on manual inspection and on-site manual control for operation and maintenance. In fields such as food processing, metallurgy, and water treatment, there are common problems such as low production efficiency, inconsistent process execution standards, insufficient stability of product and effluent quality, and high O&M costs / operation and maintenance costs. It is difficult to meet the dual requirements of industrial scale development and green low-carbon transformation. With the continuous deepening of China's industrial digital transformation, automation technology is gradually breaking through the limitations of single-device applications and extending towards integrated control of the entire process. With core advantages such as real-time data perception, intelligent optimization of process parameters, and multi-link collaborative linkage, it provides key technical support to overcome the operational bottlenecks of traditional process flows [1]. According to statistics from the Ministry of Industry and Information Technology and relevant authoritative institutions, the numerical control (NC) rate of key processes in key enterprises above designated size in China's food industry has reached 63.3%. As the core component of the raw material industry, the automation rate of key processes in the metallurgical industry has exceeded 75%. The application of automation

technology is accelerating from upgrading single point equipment to full-process collaborative control. The large-scale application of automation technology can not only significantly improve the continuity and stability of process operation, but also achieve practical results in fine energy consumption control, material loss reduction, and operation and maintenance efficiency improvement. It is an important technological path to promote the quality and efficiency improvement of traditional industries and achieve high-quality development. Based on the current development status and technological application trends of the industry, this article selects three representative process flows of food processing, metallurgy, and water treatment to systematically analyze the application scenarios, practical effects, and optimization paths of automation technology in the core processes of various industries, in order to provide feasible theoretical references and practical bases for the steady promotion of automation transformation and the construction of efficient and low-carbon production operation systems in related industries.

## **2. Industry Background and Core Values of Typical Process Automation Applications**

Traditional process industries are characterized by continuous production and rely on manual inspection and on-site manual control for long-term operation and maintenance. There are differentiated operational pain points in the fields of food processing, metallurgy, and water treatment, which significantly restrict the high-quality development of the industry. The efficiency of manual sorting in food processing is low and the rate of missed inspections is high, which not only hinders the improvement of production efficiency but also easily leads to health and safety hazards, making it difficult to meet the industry's large-scale quality control requirements [2]; The insufficient precision of manual control of process parameters in metallurgical production directly leads to high-energy-consumption and low utilization of raw materials, which is inconsistent with the energy efficiency improvement and dual-carbon development goals of the steel industry [3]; The water treatment process relies on manual sampling for water quality monitoring, but the monitoring response lags behind and the dosage of chemicals is prone to deviation, which not only affects the stability of effluent water quality but also limits the efficiency of water resource recycling. Automation technology integrates sensors, PLC control systems, intelligent execution equipment, and optimization algorithms, relying on the technological advantages of multi-source data collection, real-time situational awareness, closed-loop intelligent regulation, and efficient process linkage, to adapt to the production characteristics of process industries and form a practical technical application system, becoming the core technological path to solve the pain points of various industries' development. Its core values are reflected in four aspects. The automation transformation of the food processing and packaging processes can improve operational efficiency by 25 – 30%. The automation control of the metallurgical special steel rolling process can stably control the size error of steel plates within 0.1 millimeters and improve product processing accuracy. The intelligent dosing system in the water treatment industry can achieve a 20% increase in the utilization rate of chemicals by precisely adjusting the dosage, reducing chemical losses from the source. After the full-process automation technology transformation of the metallurgical industry, the energy consumption of core processes such as blast furnaces and converters has significantly decreased. The comprehensive energy consumption per ton of steel of top steel enterprises can achieve a reduction of 13 kg of standard coal, and the overall energy-saving and carbon reduction effect of the industry is outstanding. The penetration rate of automation technology in China's process industry is steadily increasing. The automation transformation in fields such as food, metallurgy, and water treatment has gradually evolved from single point equipment upgrades to full-process integrated control. The depth and breadth of technology

applications continue to expand, and industry technology practice and application experience continue to accumulate, laying a solid technical foundation for the optimization and upgrading of typical process flows and the high-quality development of the industry.

### **3. Application Practice of Whole Process Automation Technology in Food Processing**

The entire process of food processing covers core processes such as raw material cleaning, sorting, processing, sterilization, and packaging. The application of automation technology always closely follows the hygiene and safety bottom line of the food processing industry and the core requirements of standardized production, deeply adapting to the process characteristics of different categories such as fruits and vegetables, meat products, baked goods, etc. The raw material cleaning process is equipped with a high-pressure spray intelligent automated cleaning line, which can dynamically adjust the spray pressure and operation time based on real-time monitoring data of material cleanliness and water quality, adapt to the cleaning process requirements of different raw materials, achieve standardized and intelligent control of the cleaning process, and reduce secondary pollution caused by manual contact from the source; The processing stage is equipped with intelligent quantitative feeding and temperature control integrated automation equipment, which accurately controls the process parameters of core processes such as kneading, steaming, and frying, ensuring the consistency and stability of product quality in the same batch. The AI visual inspection system used in the raw material sorting process is based on machine vision and image recognition algorithms, which can quickly identify impurities and unqualified products in the raw materials. The sorting efficiency is more than 10 times higher than manual labor, and the missed detection rate is almost zero, strictly controlling the quality and purity of the raw materials from the source; The automated packaging line in the packaging process integrates industrial robots and high-speed conveyor belt technology to achieve unmanned operations throughout the entire process of sealing, labeling, and cartoning. This not only improves packaging efficiency by 25–30%, reduces labor costs by 25%, but also reduces human operation errors. It also achieves automated coding and data-driven traceability of packaging information, which meets the requirements of traceability management in the food industry [4]. According to the public statistics of the China Food Industry Association in 2024, the numerical control (NC) rate of key processes in China's food industry has reached 63.3%. The large-scale popularization of automation technology has solved the industry pain points of inconsistent process standards and prominent food safety hazards in traditional production modes [5]. Many leading enterprises have also built customized automated sterilization control systems based on product category characteristics, accurately matching sterilization temperature and duration according to the physical and chemical properties of different foods. While ensuring sterilization standards are met and not damaging food nutrition and flavor, production energy consumption is reduced by 15%, further improving the greenness and economy of food production.

### **4. Implementation and Efficiency Enhancement of Automation Technology in Metallurgical Production Processes**

Compared to the core pursuit of hygiene, safety, and production standardization in the food processing industry, the application of automation technology in metallurgical production focuses more on precise process control under high-temperature continuous production conditions, as well as cost reduction, efficiency improvement, and green low-carbon transformation throughout the entire process. In the core processes of metallurgical production, such as sintering, ironmaking, steelmaking, and rolling, automation technology has fully

penetrated various key production nodes and become the core support for maintaining efficient operation of production lines. It can adapt to the industry characteristics of continuous operation and complex working conditions in metallurgical production. The sintering process is equipped with intelligent batching and roasting temperature control automatic system, which accurately controls the proportion of raw materials such as iron ore powder and coke, as well as the sintering temperature curve. While improving the quality of sintered ore, it achieves a reduction of about 5% in process fuel consumption; The automation control system in the ironmaking process can dynamically adapt to the working conditions and adjust key parameters such as air volume and furnace temperature, promoting an 8% increase in blast furnace utilization coefficient and a 3% decrease in coke ratio, reducing raw material loss from the source; The converter automation blowing control system in the steelmaking process can adjust the oxygen lance height and blowing duration in real time, enabling precise control of molten steel composition and greatly improving smelting stability; The rolling process relies on artificial intelligence systems to independently generate the optimal processing plan according to order requirements, controlling the size error of steel plates within 0.1% and improving processing accuracy by 5 times compared to manual operation [6]. This type of technology application can effectively avoid the operational risks of manual labor under extreme working conditions, ensuring the continuous and safe operation of the production line. After a large steel enterprise in Hunan built a 5G+fully connected factory, more than 200 sets of core production equipment were interconnected, and the remote operation and maintenance and fault warning capabilities of the equipment were upgraded concurrently. The unplanned downtime rate was reduced by 15%, and ultimately the production efficiency was increased by 20%, the production cost was reduced by 10%, and the comprehensive energy consumption was reduced by 8%, becoming a benchmark practice for automation upgrading in the industry [7]. According to the industry operation data of the Ministry of Industry and Information Technology in 2024, the automation rate of key processes in China's metallurgical industry has exceeded 75%, and automation transformation has become the core path for enterprises to improve quality and efficiency, and implement the dual-carbon goals. The automated dust removal and intelligent monitoring system provided by the enterprise can control the dust emission concentration below  $30 \text{ mg/m}^3$ , fully meeting the strict standards of ultra-low emissions in the national steel industry.

## 5. Optimization Path and Practice of Automation Control in Water Treatment Process

Unlike discrete manufacturing and metallurgical process industries, the automation application of water treatment technology focuses on two core goals: real-time monitoring of water quality and water resource recycling. The technology covers the entire process of grid filtration, sedimentation, filtration, disinfection, and reclaimed water reuse, with the core being to achieve intelligent and precise control of water quality dynamic monitoring and treatment equipment. The traditional water treatment mode relies on manual timed sampling and detection, empirical dosing, and equipment regulation, which leads to practical problems such as lagging monitoring data, insufficient dosing accuracy, and passive equipment operation and maintenance. Automation technology can address these industry pain points in a targeted manner. The online water quality monitoring instrument can continuously detect key water quality indicators such as COD, BOD, and suspended solids, with a detection frequency of once every 10 minutes, which is 12 times more efficient than manual detection. The detection data error is strictly controlled within 5%, ensuring the real-time and accuracy of water quality data; Automated dosing equipment can dynamically adjust the dosage of chemicals based on real-time monitoring data of water quality, directly promoting a 20% increase in the utilization rate

of chemicals and reducing the consumption and waste of chemicals from the source. By optimizing the PLC control logic and building a process linkage control system, the collaborative operation of various processing links can be achieved, and the effluent qualification rate can be steadily increased to over 99.5%; Build a standardized automatic system for reclaimed water reuse, and apply the highly processed and compliant reclaimed water to scenarios such as green irrigation, industrial production water replenishment, and municipal road cleaning. The reclaimed water reuse rate of benchmark water plants in China has exceeded 60%, saving more than 100,000 tons of fresh water per water plant each year, achieving efficient cascade utilization of water resources; Configure an IoT device fault warning system to conduct real-time status monitoring of key processing equipment such as water pumps and filters around the clock. This can shorten the response time of equipment faults to within 30 minutes, helping to improve the stability of equipment operation by 35% [8]. The above data are all sourced from the review of AI water treatment technology published in the journal "Water" in 2024 and the actual measurement results of intelligent technological transformation of urban water plants in many domestic cities [9]. The construction and implementation of an automated control system for water treatment processes have effectively addressed the technical shortcomings of traditional water treatment models, providing a replicable and promotable technical practice path for the high-quality and green development of the water industry.

## 6. Common Strategies and Future Development Directions for Optimizing Automation Technology

From the practical implementation of automation technology in the three typical industries of food processing, metallurgical production, and water treatment, three core common strategies for automation optimization in the industrial field can be extracted [10]. One is to build a fully automated monitoring platform for the entire production process, with the core being to connect the data transmission links of each production link, achieve full-process data interoperability and visual scheduling, and eliminate information silos in production. The metallurgical industry uses this platform to achieve data sharing for the entire process of sintering, ironmaking, and steelmaking. The food processing and water treatment industries rely on the platform to achieve full-chain data traceability and process linkage. After the process industry is implemented on this platform, the average production collaboration efficiency is improved by more than 15%. The second is to promote refined energy consumption control, customize and optimize control logic and operating parameters for high-energy-consumption core processes in various industries. After optimization, the energy consumption of food high-temperature sterilization, metallurgical blast furnace smelting, water treatment aeration reaction and other links has been reduced by 10–15%, achieving substantial energy saving and consumption reduction effects. The third is to strengthen the intelligent operation and maintenance of equipment, rely on the IoT perception layer to collect the operating parameters of equipment around the clock, build an intelligent fault warning model, and achieve real-time monitoring of equipment operating status and abnormal warning; After being managed in this mode, the unplanned downtime rate of water treatment pumps, filters and other equipment decreased by 30%, and the operational stability of metallurgical core production equipment increased by 35%, significantly improving the O&M efficiency of industrial equipment.

The future of industrial automation technology will advance towards the direction of digital twin and deep integration of artificial intelligence. In 2024, the scale of China's industrial digital twin market will exceed 32 billion yuan. After the deployment of leading enterprises in metallurgy, food and other process industries, the average production line debugging cycle will be shortened by 30%. With the high-fidelity process digital twin model, virtual simulation and

dynamic optimization of the entire production process can be achieved, and the accuracy of process control can be improved. At the same time, the integration of 5G, Internet of Things (IoT) and automation technology continues to deepen. In 2024, China will have more than 17,000 "5G+Industrial Internet" construction projects, covering 41 industrial categories, and enabling efficient interconnection across equipment and processes [11]. In addition, automation technology will be deeply integrated with edge computing and the Industrial Internet to meet the needs of green manufacturing and provide solid technical support for the intelligent and green upgrading of industrial production processes.

## 7. Conclusion

The practical application of automation technology in the three typical industries of food processing, metallurgical production, and water treatment has achieved significant quantitative results, becoming a key technical support for various industries to break through production bottlenecks, achieve quality and efficiency improvement, and achieve green transformation. The numerical control (NC) rate of key processes in key enterprises in the food processing industry has reached 63.3%, and technologies such as AI visual sorting and automated packaging have been implemented, achieving a dual improvement in production efficiency and quality control level; The automation rate of key processes in the metallurgical industry exceeds 75%, and the full-process automation control optimizes core indicators such as blast furnace utilization coefficient, effectively reducing production energy consumption and costs; The water treatment industry achieves real-time monitoring of water quality and precise process control through automated management and control. The reclaimed water reuse rate of benchmark water plants has exceeded 60%, and the effluent qualification rate has remained stable at over 99.5%, greatly improving the efficiency of water resource utilization.

The three common optimization strategies extracted from the practice of the three major industries, namely the construction of a full-process automatic monitoring platform, refined energy consumption control, and intelligent equipment operation and maintenance, have been verified by various industries and have strong universality and practical value. After the implementation of these strategies, it can achieve practical effects such as improving production collaboration efficiency, reducing process energy consumption by 10 - 15%, and improving equipment operation stability, providing a replicable and promotable practical path for automation technology transformation in various industries.

The future development of industrial automation technology will be deeply integrated with digital twin, artificial intelligence, 5G, IoT and other technologies. In 2024, the scale of China's industrial digital twin market will exceed 32 billion yuan, and the number of "5G+Industrial Internet" construction projects will exceed 17,000. The mature application of related technologies will promote the evolution of automation technology to virtual simulation and dynamic optimization, meeting the development needs of green manufacturing. By implementing common optimization strategies and integrating emerging technologies based on their own production characteristics, various industries can further tap into the application value of automation technology and provide core support for the high-quality development of the intelligent and green industrial field.

## References

- [1] Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: a review. *Engineering*, 3(5), 616-630.
- [2] Hassoun, A., Aït-Kaddour, A., Abu-Mahfouz, A. M., Rathod, N. B., Bader, F., Barba, F. J., ... & Regenstein, J. (2023). The fourth industrial revolution in the food industry—Part I: Industry 4.0 technologies. *Critical reviews in food science and nutrition*, 63(23), 6547-6563.

- [3] Branca, T. A., Fornai, B., Colla, V., Murri, M. M., Streppa, E., & Schröder, A. J. (2020). The challenge of digitalization in the steel sector. *Metals*, 10(2), 288.
- [4] Ji, W., & Wang, L. (2019). Industrial robotic machining: a review. *The International Journal of Advanced Manufacturing Technology*, 103(1), 1239-1255.
- [5] Marczewska, M. (2024). Digital transformation: a challenging opportunity for the food industry companies. *British Food Journal*, 126(5), 2027-2040.
- [6] Wu, S. (2015). Multivariable PID control using improved state space model predictive control optimization. *Industrial & Engineering Chemistry Research*, 54(20), 5505-5513.
- [7] Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2021). Smart manufacturing and tactile internet based on 5G in industry 4.0: Challenges, applications and new trends. *Electronics*, 10(24), 3175.
- [8] Alshami, A., Ali, E., Elsayed, M., Eltoukhy, A. E., & Zayed, T. (2024). IoT innovations in sustainable water and wastewater management and water quality monitoring: a comprehensive review of advancements, implications, and future directions. *Ieee Access*, 12, 58427-58453.
- [9] Alprol, A. E., Mansour, A. T., Ibrahim, M. E. E. D., & Ashour, M. (2024). Artificial intelligence technologies revolutionizing wastewater treatment: current trends and future prospective. *Water*, 16(2), 314.
- [10] Monostori, L., Kádár, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., ... & Ueda, K. (2016). Cyber-physical systems in manufacturing. *Cirp Annals*, 65(2), 621-641.
- [11] Chandra Shekhar Rao, V., Kumarswamy, P., Phridviraj, M. S. B., Venkatramulu, S., & Subba Rao, V. (2021). 5G enabled industrial internet of things (IIoT) architecture for smart manufacturing. In *Data Engineering and Communication Technology: Proceedings of ICDECT 2020* (pp. 193-201). Singapore: Springer Singapore.