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Smart Factory Construction: A Path to Efficiency and Innovation

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ABSTRACT: *In recent years, the concept of smart factories has gained significant attention as a promising solution for enhancing productivity, efficiency, and innovation in manufacturing industries. With advancements in technologies such as artificial intelligence, robotics, Internet of Things, and big data analytics, traditional factories are transforming into smart and interconnected production systems. This paper provides an overview of the key benefits and challenges of intelligent factory construction, along with its potential impact on various aspects of the manufacturing sector.*

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I. INTRODUCTION

The development of smart factories is not about building so-called unmanned factories, but about building new factories that involve human-machine collaboration. These new smart factories can fully utilize people's flexibility to complete complex tasks, while also using robots to perform simple, repetitive, dangerous, and highly polluting tasks, thus improving work efficiency and reducing harm to human workers. Fully automated factories are costly and inefficient, while factories that involve human-machine collaboration can reduce labor costs and achieve higher efficiency. Smart factories have many advantages and are expected to replace labor-intensive factories in the future. Currently, various manufacturing companies are heading towards intelligence and automation, and the development of smart factories will be the trend for future factories.

With the implementation of the company's "smart factory" project, it is believed that in the near future, the company will quickly catch up with the pharmaceutical industry in India and strive to become a world-class international pharmaceutical company on par with Europe and the United States. By focusing on the development of new intelligent manufacturing and aiming to create a world-class pharmaceutical enterprise with international competitiveness, the company will deeply participate in and reconstruct the global value chain, drive the development of the domestic industry, and continuously elevate the quality and level of development of pharmaceutical companies in China to new heights.

II. THE DESIGN OF SMART FACTORIES

2.1 The digital upgrade and transformation

Based on the achievements of the previous digital transformation, the company has experienced the charm of enterprise digitalization and accelerated the pace of mathematical transformation, with plans to continue the digital upgrade and transformation of the following systems.

(1) ERP (Enterprise Resource Planning) system, construction direction: order allocation, material management, procurement management, sales management, warehouse management, cost management, production planning. Through the integrated system of EPR, optimize the internal processes of the company and make the operation of the company become an organic whole with the help of collaborative workflow, and infiltrate information technology into various aspects of production and operation. At the same time, the order allocation module will also be connected to the ERP systems of other sister factories of the group company, allocate different product orders to different factories for production, and then carry out financial settlement, in order to achieve the goal of "shared manufacturing".

(2) MES (Manufacturing Execution System) system, planning and scheduling, production process execution control, electronic approval records. By using IoT technology, the company will realize real-time collection and application of workshop production data, achieve transparency in the production process of the factory, and effectively monitor the entire production process, ultimately achieving the goal of improving productivity.

(3) SCADA (Supervisory Control and Data Acquisition) system, centralized collection of equipment data, establishment of SCADA covering the production line, meeting the requirements of GMP regulations for production data collection and storage, solving the problem of data isolation, and achieving high integration of data under one platform. Achieve full integration of data from Level 0 to Level 4, ensuring data integrity and traceability, and providing data for MES and other systems. Change the previous decentralized monitoring mode, realize centralized control of the production process, and improve the operational efficiency and labor productivity of the system. Timely alarm for deviations and failures in the production process, transforming post-event management into real-time online management. According to the characteristics and requirements of the production process, the main parameters of the process including temperature, pressure, liquid level, flow rate, weighing, combustible gas, and equipment operating status can be displayed, recorded, adjusted, accumulated, controlled, chained, alarmed, printed, and online modified; shutdown operation can be performed on the running equipment. Important process parameters have automatic adjustment, with single-parameter adjustment as the main method, and out-of-limit alarm or chaining for potentially dangerous process parameters to ensure safe production.

(4) DCS (Distributed Control System) system, production automation control, using PLC for basic equipment control and DCS system for centralized control. The entire production process adopts automation control, which has significant advantages in investment savings and low energy consumption. Improve the automation level of the system. When equipment failure or human error causes a danger, the system will automatically alarm, switch to backup equipment, activate interlock protection devices, and safety devices, and perform a series of automatic operations such as safe shutdown to ensure system safety. Special interlocking protection, safety devices, and emergency control systems are set up to improve the reliability of system safety in case of accidents. Monitoring and warning facilities are installed in places where hazardous chemicals are produced, stored, and used.

(5) Digital security platform, comprehensive security monitoring, integrated video surveillance, emergency command management, personnel positioning management, etc. AI video perception provides AI video supervision for key regulated processes such as production, installation, transportation, unloading, and storage in factories and enterprises. Through artificial intelligence algorithms, various risk factors are monitored 24/7, problems are detected in a timely manner, and automatic warnings are issued. The analysis of behaviors includes not wearing safety helmets, leaving posts, sleeping on duty, smoking, not wearing protective equipment, smoke, abnormal stay, unauthorized area entry, etc., and supports configuration of behavior analysis functions for cameras. Warning management mainly sets threshold values, related videos, push rules, and video analysis for monitoring variables such as temperature, pressure, liquid level, and humidity in the production process. Emergency command provides a series of intelligent applications for the emergency disposal process, including event classification management, event initiation response, one-click resource dispatching, analysis and judgment of the disposal process, closed-loop tracking of tasks, and intelligent matching of plans, to provide information support for the rapid disposal of emergencies. It also supports linkage with large screens to display the entire command and dispatch process. Emergency plan management structurally and digitally manages emergency plans, realizes one-click startup of plan response process, and enables rapid rescue. Intelligent metering uses the innovative concept of Internet + meter reading. It combines embedded AI camera meter reading technology with NB-IoT (Narrowband Internet of Things) or 5G technology to build an AI intelligent meter reading system based on low-power wide area network (LPWAN) technology, which is suitable for various types of digital, pointer, and liquid level meters.

(6) Hyperconverged platform, simplifying the infrastructure, integrating the data of various systems into one place through the architecture of computation, storage, network, and virtualization software. By providing one-stop management and an intelligent data dashboard, it provides data support for the decision-making of the company's leadership, thereby improving the company's operational efficiency. Through the step-by-step construction of various systems mentioned above and the later integration, the construction of "Intelligent Factory Industrial Internet of Things Platform" is ultimately achieved.

2.2 Design of Industrial IoT Platform for Smart Factory

With big data, networking, and massive computing as the foundation, the platform utilizes core intelligent logic to perform tasks such as judgment, analysis, mining, evaluation, prediction, optimization, and collaboration. It achieves organic integration and deep collaboration of computing, communication, and control, through technology means such as intelligent logic processing, analysis, mining, evaluation, prediction, optimization, and collaboration.

(1) The system is designed with a layered structure, consisting of three layers: device layer (adapters), data support layer (cloud platform), and application layer.

(2) The data acquisition layer installs an adapter on the devices to collect and receive information from the corresponding devices.

(3) The network layer authenticates the adapters, receives the data sent by them, and can also send commands and data to them. After receiving the device information, the platform processes the data using core intelligent logic to perform tasks such as judgment, analysis, mining, evaluation, prediction, optimization, and collaboration. Finally, the processed information is distributed to the places where it needs to be displayed, such as operation platforms, mobile apps, and large screen monitors.

(4) The management layer refers to the application of the collected data, which is relatively flexible. For example, it can present the distribution of all customers, the overall equipment reliability, and remote monitoring of equipment in a macroscopic manner. Alternatively, it can display the changes of a certain data for a specific customer during a certain period of time using curves. It can also use charts to show the comprehensive status of all running equipment, etc. By combining with intelligent factory MRS systems and ERP systems, a standardized production management information platform is established to achieve information interconnection and communication between the field control layer and the management layer, thereby improving the core competitiveness of the enterprise. The basic network topology structure of smart factory industrial IoT platform is illustrated as in Figures1.

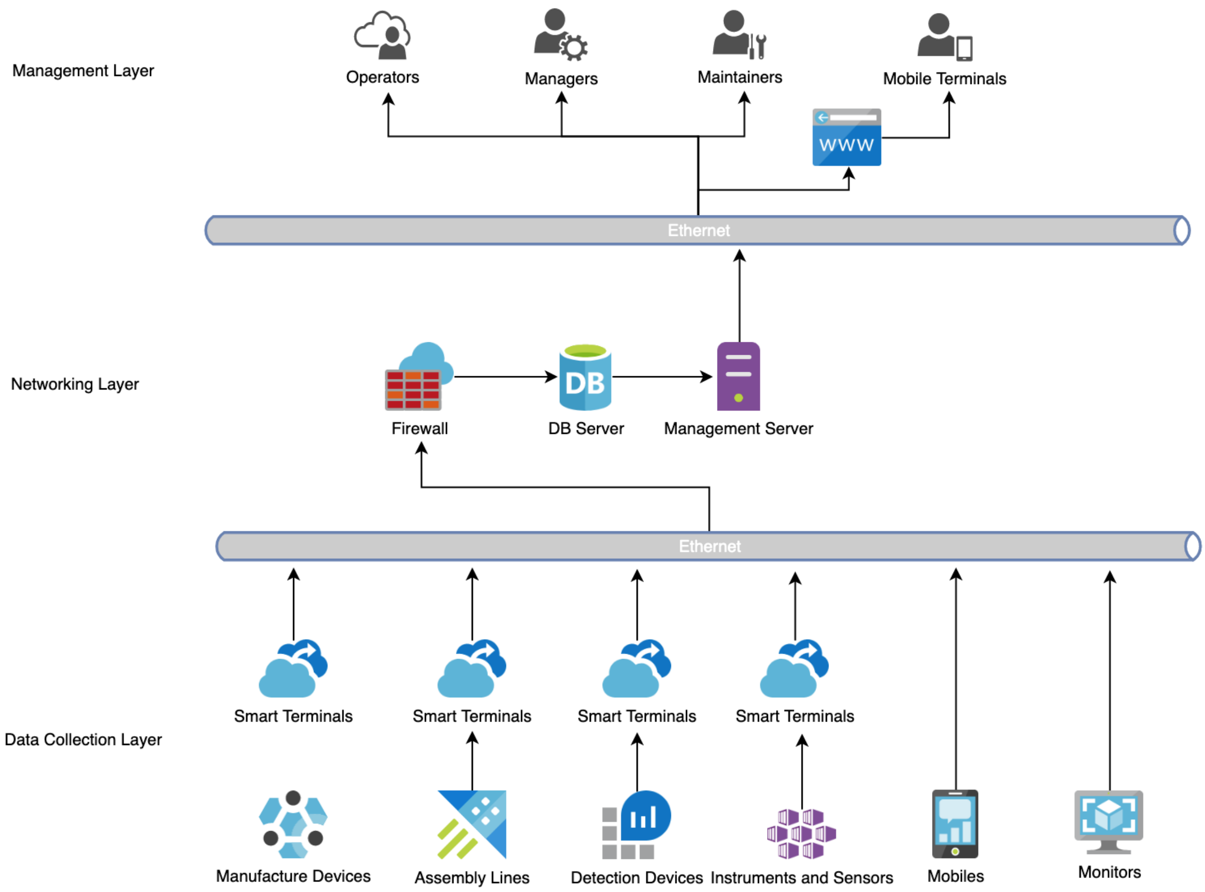

Figure 1: Basic Network Topology Structure of Smart Factory Industrial IoT Platform

Various wireless industrial equipment sensors are used to collect data, enabling timely and accurate reporting of operational data and fault data to the cloud platform, as well as analysis, storage, and cost savings in comparison to traditional manual recording. The incoming equipment is monitored in real-time for online/offline status, battery level, and operating parameters through adapters. Through analysis of the reported information, the real-time or periodic power consumption and operating time of the equipment are calculated. Extraction equipment is monitored in real-time for online/offline status, operating parameters, and through analysis of this information, the real-time or periodic working time, production yield, and real-time alarm information of the equipment are calculated. Fermentation equipment is monitored in real-time for online/offline status, battery level, and through analysis of this information, the real-time or periodic working time, and real-time alarm information of the equipment are calculated.

A complete remote detection system is developed to achieve communication between equipment data and client terminals such as mobile phones and PCs, forming a three-way communication ecosystem between equipment, servers, and terminals. The industrial IoT platform of the smart factory connects all isolated devices in the workshop to the cloud server through adapters. The cloud platform analyzes this data and presents comprehensive multidimensional analysis reports to monitoring personnel. Through these data reports, monitoring personnel can intuitively understand the operating status of factory equipment, production efficiency, worker efficiency, efficiency of resolving equipment alarms, alarm distribution, and other multidimensional data. This helps the company quickly identify production bottlenecks, improve production efficiency, and maintain strict control over product quality. The industrial IoT platform of the smart factory also incorporates video monitoring capabilities, allowing management personnel to remotely monitor the working conditions of key nodes in the workshop, providing a more intuitive view of the workshop's operations.

2.3 Shared Manufacturing

Shared manufacturing, also known as manufacturing sharing or sharing of manufacturing resources, is the application of the sharing economy in the field of production and manufacturing. It is a new model and form that utilizes the concept of sharing to aggregate dispersed and idle production resources and dynamically share them with demand parties throughout the various stages of production and manufacturing. During the period of the 14th Five-Year Plan, guided by the "Guiding Opinions on Further Promoting the Development of Service-oriented Manufacturing," shared manufacturing will become a hot topic. In response to the government's call, Kangnengbei Group, utilizing its own advantages, is taking the lead in piloting within the group. In addition to Zhejiang Jinhua Kangnengbei Biopharmaceutical Co., Ltd., two other subsidiaries are undergoing technological transformation and preparing in advance by developing ERP or MES systems and reserving interfaces for integration into the "Intelligent Factory" industrial IoT platform of Jinxi. By accepting the scheduling arrangements of Jinxi's "Intelligent Factory" during production scheduling, waste of production output is avoided and production efficiency is improved. Ultimately, through this pilot project, the entire industry chain can be connected, creating a shared platform for interactive participation. Expected objectives of project implementation are described as follows.

2.3.1 Economic Benefits

(1) Optimized the enterprise's production management mode, strengthened process management and control, and achieved fine management.
(2) The control system is organically combined with the management system, achieving data sharing and strengthening the collaborative office capabilities of various departments, thus improving work efficiency.
(3) Improved the timeliness and accuracy of production data analysis and statistics, addressing the lag in information and report data that results in sluggish enterprise response and the inability to timely avoid and address errors.
(4) Provided effective and standardized management support for the quality inspection of enterprise's pharmaceutical products.
(5) Established a standardized production management information platform, enabling information connectivity between the on-site control layer and the management layer within the enterprise, thereby enhancing the core competitiveness of the enterprise.

Expected economic benefits of the project are that the establishment of the "Intelligent Factory" can improve production efficiency by more than 10%, increase inspection efficiency by more than 2 times, and achieve a programming efficiency of over 85% for process layout. By replacing labor with robots and achieving unmanned, intelligent, and efficient operation in the storage area, the production efficiency of factory products can be effectively improved, and the order delivery cycle can be reduced by 6% while reducing costs by about 5%. After the project is completed, it will be able to achieve an annual production capacity of 730 tons of high-end bulk drug materials and increase the original raw material production capacity to 800 tons, with an estimated annual sales revenue of over 1 billion yuan and an additional profit and tax of 200 million yuan.

2.3.2 Social Benefits

By utilizing IoT technology and equipment monitoring technology, information management and services are strengthened. The entire production and sales process can be clearly understood, the controllability of the production process is improved, human intervention on the production line is reduced, and production line data can be collected accurately and in real-time. In addition, with the integration of green intelligent methods and intelligent systems, an efficient, energy-saving, environmentally friendly, and comfortable factory is constructed.

(1) Strengthened industry-specific technical accumulation and talent cultivation.

The implementation of this project has cultivated a technical and management team within the company that is familiar with intelligent manufacturing systems, intelligent production processes, and project development. This lays a solid foundation for the development of the enterprise and enhances talent and production capabilities while achieving efficient production and objective economic benefits.

(2) Time-saving

By utilizing IoT technology and equipment monitoring technology, the core processes of the entire production line are clearly understood, the controllability of the production process is improved, production plans are reasonably arranged based on collected production data, equipment utilization is improved, and production cycles are shortened, accelerating production progress.

(3) Cost reduction

By utilizing IoT technology and equipment monitoring technology to monitor key production parameters of equipment, the utilization rate of operating equipment is improved through data analysis and unnecessary energy consumption is reduced. For example, using AGV intelligent loading and unloading robot systems to replace labor, the storage area can be operated without human intervention, making it intelligent, efficient, and cost-effective, reducing labor costs.

(4) Quality improvement

Through the construction of intelligent manufacturing and remote monitoring systems, the project provides an opportunity to establish enterprise quality control standards, improve the quality of technical information, record project changes and validity periods for quality tracing, reduce errors caused by manual recording, and improve inspection efficiency by more than 2 times. By implementing quality control of products, analyzing the causes of key problems, and improving overall product quality.

(5) Energy-saving and environmental protection

Economic development has promoted social progress and improved people’s living standards, but it has also increased the exploitation and excessive use of natural resources, as well as issues such as energy waste and environmental pollution. The company has always responded to the national call for “energy conservation, emission reduction,” and “carbon neutrality,” and strives to fulfill its social responsibilities as an enterprise. It is believed that after the implementation of the “Intelligent Factory,” by streamlining unnecessary personnel on the production line, prioritizing production processes, improving production processes, and enhancing the overall efficiency of the company, there will be a significant improvement in the energy-saving use of water, electricity, gas, and other energy sources. It is estimated that it can save more than 15% of water usage and more than 5% of electricity usage annually, making a contribution to local green and environmental protection.

III. RESULTS AND DISCUSSION

The first section highlights the advantages brought about by smart factories. By integrating advanced technologies, these factories optimize production processes, reduce downtime, minimize errors, and enhance overall efficiency. Real-time data collection and analysis enable predictive maintenance, leading to cost savings and improved equipment reliability. Moreover, smart factories foster innovation by promoting seamless collaboration between humans and machines, allowing for customization, rapid prototyping, and quick adaptation to changing market demands.

However, the implementation of smart factories also poses certain challenges. The second section discusses these obstacles and explores strategies to address them. Cybersecurity threats, data privacy concerns, and the need for upskilling and reskilling the workforce are among the major challenges faced in building smart factories. Collaboration between industry, academia, and government is crucial to develop comprehensive frameworks and regulations to ensure secure and ethical practices in this domain. Additionally, investing in training programs and skill development initiatives can empower workers to adapt to the evolving work environment.

Lastly, we presents the potential impact of smart factory construction on the manufacturing sector. It explores how this paradigm shift can lead to increased global competitiveness, sustainable production practices, reduced environmental footprints, and improved quality control. Furthermore, the adoption of smart factories can create new job opportunities, especially in areas such as data analysis, cybersecurity, and process optimization.

In conclusion, smart factory construction offers immense potential for revolutionizing the manufacturing sector. While it brings numerous benefits in terms of efficiency, innovation, and competitiveness, there are also challenges to be addressed. By focusing on collaboration, education, and regulation, stakeholders can navigate these challenges to fully realize the transformative power of smart factories.

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