Research on the Function Optimization of the Bulk Grain Transportation Central Control System

Xuelin Wang1,1*, Hankun Shi2
1 China Waterborne Transport Research Institute, Beijing, 100088, China
2 China Waterborne Transport Research Institute, Beijing, 100088, China
*Corresponding author’s e-mail: 17801034993@163.com

Abstract. With the rapid advancement of the guidance for port transformation and upgrading, in view of the lagging automation of bulk terminals, the low level of intelligent information, and the urgent needs for the transformation and upgrading of bulk terminals, this paper optimizes the central control system for bulk grain transportation, and implements the framework, technology, and functions of the central control system for bulk grain transportation. Based on the research of the basic functions of the existing central control system for bulk grain transportation, combined with actual needs, the functional characteristics of the central control system are optimized and researched. The warehouse preparation and transfer process is optimized, the web publishing function is added, the information management is optimized, and the alarm function is improved. The overall characteristics and intelligent level of the central control system for bulk grain transportation is improved, which has guiding significance for the intelligent construction of bulk grain transportation in ports.

1. Introduction
China's ports are at a new stage of development, and many ports are actively trying to transform and upgrade[1]. In June 2014, the Ministry of Transport issued the "Guiding Opinions on Promoting the Transformation and Upgrade of Ports", the document emphasizes the need to promote the promotion and application of information and communications technology in ports and promote the construction of smart ports[2]. At present, container ports are developing rapidly, especially the development of fully-automated container terminals[3]. Due to the complexity and variety of freight, dry bulk terminals have a late start in intelligent development. It is relatively backward, and the degree of intelligent information is low[4]. How to improve the intelligent degree of bulk terminals has become one of the problems that need to be solved at present. The central control system is an indispensable part of the intelligent process of the port. The optimization of the control system performance can improve the convenience of operators and the safety of the production process. Therefore, the optimization research based on the central control system of bulk cargo terminal transportation has certain theoretical value and practical significance.

2. Central control system for bulk grain transportation
Bulk terminal refers to the terminal for loading and unloading bulk cargo. Bulk cargo mainly includes grain, ore, coal, etc. The process of loading and unloading of bulk grain terminal is shown in Figure 1. This article mainly studies the function optimization of the central control system of bulk grain terminal in bulk terminal.
The bulk grain terminal transportation system includes two parts of equipment operation and monitoring management. The equipment operation part mainly includes on-site ship unloading, loading, and transportation equipment, and the monitoring and management part mainly includes the central control system and information system\[5-6\]. The central control system remotely controls the belt conveyor, scraper, elevator and gate valve equipment in the loading and unloading equipment to complete the process of loading and unloading grain into and out of the warehouse.

2.1 System Overview

The central control system is the core of the bulk grain terminal transportation system. Its structure is shown in Figure 2. The central control system consists of data management module, PLC control module, human-computer interaction module, and user management module. The central control system completes instruction communication and program control through data management and database storage, and further realizes remote operation of equipment and processes. In this paper, we take the Xiamen Store of Central Reserve Grain as an example to study the design and optimization of the central control system for bulk grain transportation.

![Central control system diagram](image-url)
The central control system adopts a distributed automatic control method, central control room (CCR) and sub-control stations are set up. Each sub-control station and the central control room are connected through an industrial dedicated network to form a unified control system network. The system sends control commands to the PLC module through the human-machine interaction module, and uses the PLC module to perform data collection and output control on the equipment in the entire bulk grain transportation system. The PLC module guarantees the stability and reliability of the system and directly controls the equipment operation and process operation, the human-computer interaction module can intuitively and dynamically display the operation status of each device and monitor the real-time process status.

2.2 PLC module characteristics

The PLC module has the characteristics of easy design, convenient maintenance, flexible modification and distributed functions. It has been widely used in steel, petrochemical, electric power, machinery manufacturing, automotive, light textile and transportation industries[7], the PLC module can complete switching and analog control of various difficulties[8]. The PLC module can implement functions such as process control and data communication processing. The interface with other control systems is networked. Data is shared through the human-machine interaction module network to complete the interlocking start and stop between the system interfaces. In the system flow of the bulk grain terminal, there are belt conveyors, scrapers, elevators, gate valves and other equipment. After establishing a data communication network with the PLC, the human-machine interactive interface is used to control the equipment start-stop, process start-stop and its operation mode.

Hardware and topology based on Quantum Ethernet I/O Hot Standby is used. Quantum Hot Standby is an industrial control platform designed to provide automatic redundancy for a variety of conditions[9], programmatically to detect and respond to defined system conditionss, the Quantum Hot Standby system automatically allows the standby controller to take over control of the process, making it the new primary controller[10]. Topology of PLC control system based on Quantum Ethernet I/O Hot Standby. As shown in Figure 3, 1A+2A is the CPU and copro of the main controller, 1B+2B is the CPU and copro standby controller, 3 is the CPU synchronous fiber optic circuit. 4A+4B is the main power supply and backup power supply, 5A+5B is the main remote and backup remote I/O master station module, 6 is Ethernet connection, 7 is Ethernet remote I/O substation, and 8 is Unity Pro workstation. The PLC master station adopts the dual-machine hot standby method. The PLC master station and each remote I/O substation use Ethernet-based remote I/O communication. The master station and each substation use the Ethernet ring network. The device includes all necessary processors, racks, interface modules, communication modules, input and output modules, power components, and other structural components. Supports various field buses including Modbus TCP/IP industrial Ethernet, Modbus, Modbus Plus and so on. The PLC system adopts network redundant configuration to ensure the reliability of the system.

Figure 3. PLC control system topology
2.3 Human-computer interaction module characteristics

The human-computer interaction module is responsible for connecting the operation station, the monitoring system server, and the PLC host together. The communication between PLC and human-machine interaction module uses industrial Ethernet, and the communication bandwidth is 100Mbps. In order to ensure the response speed and operational reliability of the human-machine interaction module, the PLC system should be provided with a separate Ethernet communication module responsible for data exchange with the monitoring system server. This project uses the iFIX 5.8 version. iFIX 5.8 is an open HMI/SCADA component product, which is suitable for monitoring the production process. In order to make the module reproducible and easy to popularize, the iFIX system designers have adopted a component approach and can be perfectly compatible with a variety of industrial control products and third-party software to achieve a variety of control functions, thereby achieving multi-applicability and high reliability and the purpose of improving production efficiency. The human-machine interaction module has functions such as on-site monitoring, process selection and control, fault alarm and equipment control.

3. The main control functions of the central control system

The central control system mainly implements the control function of the field equipment by the human-computer interaction interface, and simultaneously collects the signals of various detection equipment and sensors to obtain the operating status of the field equipment, and performs real-time monitoring display. Operators can uniformly manage and control field equipment and work processes through computer operating terminals. In order to ensure the safety and stability of production operations, the control methods are generally divided into on-site manual methods, centralized manual methods, and automatic control methods.

On-site manual control, as an auxiliary control method, is usually completed by a field operation box next to the equipment. This method is used when the mechanical equipment is commissioned, the machinery is maintained, and the central control room does not control the remote control system. The operation box is equipped with a "remote/local" transfer switch. When the transfer switch is in the "local" position, the equipment can be started and stopped at the scene. At this time, the equipment does not have an interlock relationship. Centralized manual control in the central control room is another auxiliary control method. This method is implemented in the central control room through a computer operation terminal. When the on-site "remote/local" switch is in the remote position and the "auto/manual" switch on the monitoring screen of the central control room operation terminal is turned to the manual position, the operator can operate the on-site controlled equipment through the manual buttons on the control terminal in the central control room. The central control room automatic control method is the main control method. When the "auto/manual" switch on the monitoring screen of the computer control terminal in the central control room is turned to "automatic" and the transfer switch on the field operation box of the selected process-related equipment is in the "remote" position, the operator can use the operation terminal Keyboard or mouse for process selection, process start and stop, and job volume setting. Under this control mode, the related equipment in the process has an interlock relationship.

The main functions of the central control system in job production are classified as follows:

- **Centralized automatic/centralized manual**: The central control system can switch between "Centralized Automatic" and "Centralized Manual".
- **Process pre-selection**: Pre-selection and selection of processes to ensure the safety of process operations.
- **Process cancellation**: The selected process will be canceled. After canceling the process, if you want to start the process, you need to re-select the process.
- **Process stop**: The process that will stop running. The equipment in the process will be stopped in the order of "flow down".
- **Process start**: The selected process will be started. The equipment in the process will be started in the order of "counter grain flow" and delayed.
4. Research on Function Optimization of Central Control System

The transportation demand of bulk grain terminals is increasing year by year. Improving the production and transportation efficiency is the focus of transformation and upgrading of bulk grain terminals. The development trend of the central control system of the bulk grain terminal is that the structure of the control system is getting simpler and simpler, the functions are more and more intelligent, and the operation is getting easier and easier. Based on the completion of the basic functions of the central control system, this study optimizes the core functions of the central control system in order to improve the efficiency of production and transportation and the intelligent level of the system.

4.1 Optimize the reserve rollover process

When carrying out bulk grain transportation operations at the port, both the warehouse entry process and warehouse exit process are common process categories. The existing model is optimized during the warehouse entry process, and the reserve function is added. After commissioning, it is found that selecting the reserve in advance can improve operating efficiency. When you click the process reserve button, you will perform the warehouse entry and transfer operations, and switch the warehouse entry and reserve operations. When the exit process is running, you click the warehouse exit transfer button, you will perform the warehouse transfer operations, and switch out of the warehouse reserve. For different requirements of stocking time, you can also select stocking in advance on the main screen before the process starts, as shown in Figure 4. The optimization of the warehouse rollover process has increased the convenience of the operation, and also improved the safety of warehouse preparation and the efficiency of entering and exiting the warehouse.

4.2 WEB publishing function

In order to accelerate the pace of port informatization construction and improve the level of informatization monitoring, it is essential to build a web-based data release system. The communication interface and permissions are set in the central control system. As shown in Figure 5, the configuration software iFix Webspace runs online in real time and accesses the Web server to achieve the web publishing function. Enterprising customers can access the authorized Web server IP through the intranet at any location. After entering the internal account and password, they can log in to the human-computer interaction module and obtain the same full operation rights as the computer terminal in the control room. While monitoring the real-time status of the port bulk grain transportation system anytime, anywhere, you can also operate the equipment and processes to fully realize the data release and status sharing of the real-time database, and achieve zero distance synchronization between the information system and the bulk grain transportation system.
4.3 Improve fault reminder function
In the process operation phase, according to the different nature of the process, the shallow round warehouse is designed to automatically switch according to the set amount or level status, and when the equipment fails, it will stop according to the fault shutdown mode, and give an alarm prompt to show the failure. After the fault is removed, you can press the start button to restart. According to the site requirements of the alarm, you can choose to display the alarm or silence the alarm at any time. This improves the function of the alarm reminder and optimizes the form of the fault reminder.

4.4 Optimize monitoring server function
The monitoring server is responsible for collecting various data information from the PLC controller into the software iFix of the human-computer interaction module. The monitoring server allows each operation terminal to access the server through the network to achieve the corresponding monitoring and operation functions. The monitoring server is responsible for transmitting the corresponding production data to the information management system server, and can provide the necessary monitoring screen display functions to the central control system, making the operation more intelligent. This research set up two monitoring servers. The monitoring server communicates with the PLC through Industrial Ethernet and the monitoring terminal communicates with the monitoring server through Industrial Ethernet. The setting of the monitoring server can improve the stability and security of the central control system.

4.5 Realize the interface with the information management system
The central control system and information management system are two very important parts in production management. These two parts together ensure the stability and orderliness of the real-time production process and the comprehensive and accurate operation history backtracking. The communication between the central control system and the information management system uses industrial Ethernet. The corresponding hardware and software interfaces are reserved in the central control system, and the necessary production and operation data is provided to the information management system database through the information management server interface. The information management system can simultaneously collect data from three sets of video systems (including industrial television monitoring systems, intelligent security systems, and online monitoring systems), and use intelligent algorithms to analyze and process them. It has alarm history storage, equipment status records, danger warning, and cargo. Functions such as volume reminders provide auxiliary decision-making and function optimization for the central control system.

5. Conclusions
With the acceleration of the construction of smart ports, the intelligent construction of bulk terminals is urgent. The project designed and built the corresponding application function module for the central
control system of the bulk grain terminal, and compared and analyzed the main framework, technical characteristics and functional requirements of the central control system. In addition to completing the basic functions of the central control system, the project combined with the actual needs of intelligence to carry out functional optimization research and development of the central control system. It added a web publishing function, improved the reserve and transfer functions, and the alarm function. The docking of the system optimizes the overall characteristics of the central control system. This study has intelligently upgraded the central control system to a certain extent, improved the overall efficiency of port bulk grain production and transportation, and has the conditions for promotion at similar terminals.

References
[1] Chen Pei. (2014) Hub of Tianjin Port for Resource Allocation in Transformation and Upgrade of Port [J]. Port Science and Technology, 4: 46-47.
[2] Wang Xuelin. (2015) New Normal of Port Development Based on "Internet +" [J]. Chinese Port, 11: 22-23.
[3] Du Chao, Wang Jiao'e, Mo Huihui. (2016) Study on the Spatial Pattern and Complexity of China's Container Shipping Network [J]. Resources and Environment in the Yangtze River Basin, 25: 190-198.
[4] Sun Ju. (2019) "Strengthening the Intelligent Application of Dry Bulk Terminals." China Water Transport (Second Half), 1: 55.
[5] Qiao Chaoqi, Lü Chongxiao, Yan Yujun. (2013) Design and implementation of the central control system of the Huanghua Port Phase III project [J]. China Port Construction, 1 (Z1): 914.
[6] Zeng Fei, et al. (2017) Intelligent Monitoring System for Large Belt Conveyors Based on the Internet of Things. Journal of Nantong University, 16: 2: 12-16.
[7] Zhang Hong, Long Wei, Zhang Lijian. (2006) Steel Plant Waste Acid Water Treatment Control System Based on PLC and Configuration Software[J]. Microcomputer Information, 11: 109-111.
[8] Wu Fuxian, Gao Jilei, and Li Zhenghua. (2014) Application of Automatic Control in Coal Mine Underground Belt Transport. Henan Science and Technology, 15: 88.
[9] Zhao Huijun. (2014) Talking about the Application of Kunpeng Series PLC in the Heat Exchange Station [J]. Science and Technology and Enterprise, 1: 128-128.
[10] Liang Xiuyi. (2017) Schneider Electric PLC: Innovation Based on User Needs. Automation Expo, 34: 6: 24-26.