The Control System of Mountainous Multi-function Miniature Pile Drill WZFT

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Abstract. With the development of the power industry in China, in order to promote the further efficient and comprehensive development of the power industry in China, it is necessary to achieve precise mechanical automation in power engineering to meet the needs of the power industry in the new era, so that the level of automation of power machinery and equipment demand is higher and higher. Especially in the narrow, special field, mountain construction surface drilling operations of manpower and time cost of the project are heavier, to develop advanced first-class related drilling equipment is necessary, so as to improve the power industry punch into miniature pile operation automation level and efficiency, realize the equipment localization, To meet the requirements of high efficiency in the construction of power engineering, reduce the safety risk of construction personnel, greatly reduce the cost of the project, prevent soil erosion and protect the environment. The control system designed in this paper is to complete the power industry special multi-functional drilling equipment, to achieve the construction of drilling equipment used to drill into miniature piles, mainly through the open CAN bus control, and produced by Jiangxi Dongrui Machinery Co., Ltd., to achieve the control of high real-time and intelligence.

Keywords: Electric power, Miniature pile, Can bus, Intelligent, Drill, The Real Time.

1. Introduction
The draft of the 14th Five-Year Plan and the Outline of the Long-term Goals for 2035 (hereinafter referred to as the draft of the 14th Five-Year Plan), deliberated at the National People's Congress and the National People's Congress in 2021, points out the direction, principles and key points of work for China's economic and social development in the next five to 15 years, which is of great significance. Based on the new development stage, implementing the new development concept, constructing the new development pattern, and promoting high-quality development will be the main line of China's economic and social development in the next stage, which will profoundly affect all aspects of national development, including the future development of China's power system.

The draft outline of the 14th Five-Year Plan puts more emphasis on the new concept of development and high-quality development, on the concept of systems, on the relationship between coordinated development and security, and on accelerating the construction of a new pattern of double-cycle development. Looking at the draft of the 14th Five-Year Plan, "coordinated development and security" is the biggest prerequisite and work requirement for all work, especially for industries and fields related to national economy and people's livelihood and national economic security, including energy security. Among them, it is discussed to optimize the construction of the main grid and trans-regional transmission channels, accelerate the construction of the smart grid, improve the...
interactive response capacity of the grid with the generation side and the demand side, improve the transmission and distribution capacity to remote areas, and improve the utilization rate of the UHV transmission channels. Accelerate the intelligent transformation of power grid infrastructure and the construction of smart micro grid. It is clear that improving the utilization efficiency of the stock UHV transmission channel is crucial to the national strategy of power transmission from west to east and from north to south. Therefore, precise mechanical automation should be realized in power engineering to meet the needs of the power industry in the new era. Especially in the narrow, special field, mountain construction surface drilling operations takes human gravity and time cost of the project, to develop advanced first-class related drilling equipment is necessary, so as to improve the power industry punch into miniature pile operation automation level and efficiency, realize the equipment localization. To meet the requirements of high efficiency in the construction of power engineering, reduce the safety risk of construction personnel, greatly reduce the cost of the project, prevent soil erosion and protect the environment.

The design of the optimal control system is to complete the power industry special multi-functional drilling equipment, to realize the power construction with it to drill piles, mainly through the open CAN bus to realize the data communication between controllers and sensors and to complete the high real-time control and intelligence of the drilling rig.

2. Structure of Control System of Mountainous Multi-Functional Micro-Pile Drill

In electric power engineering, micro-pile is widely used for its characteristics such as small concrete square amount, convenient construction equipment, small and flexible construction scheme, low economic cost and low construction space requirements. In practical engineering, the scheme of small diameter multi-pile and pile group foundation is adopted, so as to reduce the requirement of drilling rig's pore-forming performance, and make drilling rig's equipment can be further lightweight [1]. The designed rig equipment is shown in the figure below. As shown in figure 1.

![Multi-functional miniature pile drill.](image)

**Figure 1.** Multi-functional miniature pile drill.

In consideration of the diameter and depth design of micro-pile, according to the Technical Code for Building Pile Foundations (JGJ94-2008) and the Technical Regulations for Transmission Line Micro-pile Foundations (Q/GDW 1863/2012), the calculation method is given to obtain the required range of parameters for the diameter and depth of micro-pile:

Mini-pile diameters are about 350mm, and the hole depth of Mini-pile up to 16m is the parameter used as the standard Mini-pile object [2].

This paper designs the composition of the control system of the drill: the programmable controller (PLC) as the control center, the control unit digitalization, combined with the fieldbus CAN communication technology and industrial computer, touch screen and other digital devices to form a relatively perfect control scheme, to meet all the functional requirements of the mountainous multi-functional micro-pile drill; the main technical requirements of the designed drilling rig are as follows (Table 1).
Table 1. Multi-function drill parameters table.

| Serial number | Description | Specification |
|----------------|-------------|---------------|
| 1. Type of drill | DTH drill | |
| 2. Engine power | 260-350 (KW) | |
| 3. Maximum working pressure of air compressor | 20-35 (bar) | |
| 4. Displacement | 10-25 m³/min | |
| 5. Perforation diameters | Φ350mm | |
| 6. The maximum depth is | 16m | |
| 7. Dust removal method with wet dust removal system | | |
| 8. Torque of rotary head | 2000-6000N·m | |
| 9. Drill pipe library 5+1 | 1 main rod +5 pairs of rod | |
| 10. The chassis type can be adjusted flat | | |
| 11. The walking speed is | 3.5km/h | |
| 12. Ground clearance | 350mm | |
| 13. Swing Angle of crawler frame is | ±5° | |
| 14. The maximum speed of propelling beam is | 0.8-1.0m/s | |
| 15. The maximum propulsion force is | 30-45kN | |
| 16. The maximum pulling force is | 50-70kN | |
| 17. Propulsion compensation | 1200-2000mm | |
| 18. Propulsion stroke is | 5000-7000mm | |
| 19. Total length: | 9500-10000mm | |
| 20. Angle Adjustment Equips Angle Sensor | | |

Lubrication method the impactor drill pipe is lubricated with lubrication device Main joints such as drilling rack and oil cylinder are equipped with automatic lubrication system [3]. In order to ensure the realization of highly automated drilling rig control platform foundation, the machine is equipped with high-precision servo hydraulic cylinder, rather than the traditional cylinder, the control accuracy of up to 12 bits, completely replace the traditional encoder, to change the hole depth counting method; It adopts imported electrically controlled proportional valve, electrically controlled pressure regulating valve and solenoid valve with low hysteresis to meet the needs of high real-time response system. It completely replaces the hydraulic control handle of the traditional drill with electronic control handle to achieve zero tubing in the whole cockpit. The use of load-sensitive control unit can automatically match the system pressure according to the load conditions, greatly reducing the fuel consumption of the vehicle. Equipped with a walking motor with hardened gear and nitriding gear ring, so that its bearing capacity is strong, reliable operation and low noise characteristics. In this paper, the CAN schematic diagram of the control system of the drilling rig is designed:
Human-computer interaction equipment in cab: console part, handle and each switch knob, touch screen. The screen, handles and switches are connected with the body controller by means of analog or CAN communication, as shown in figure 2.

3. Performance Requirements of Control System of Mountainous Multi-Functional Micro-Pile Drill

The mountainous multi-function micro-pile drilling machine that the design goal is to realize unmanned and intelligent, so the real-time performance of the control system is very high. According to the performance of the control system, its evaluation can be divided into dynamic performance index and steady performance Index. The dynamic process of the system provides the stability, response speed and damping of the system, which is represented by the form of attenuation, divergence and constant amplitude oscillation, and is described by the dynamic performance index. The steady-state performance of the system is described by the steady-state error, which is usually measured or calculated under the action of step function, slope function or acceleration function. Steady-state error is a performance index to describe the steady-state performance of the system. Steady-state error is usually measured under the action of step function in rig control. If the output of the system is not equal to the input or the deterministic function of the input in a certain time, the system has a steady-state error. Steady-state error is a measure of the system's control accuracy or ability to resist disturbance.

For drill to ensure the damping coefficient of the stability, response speed and dynamic performance index, in order to achieve accurate unmanned and intelligent operation, the steady-state error in steady state performance deserves more attention, mainly under the introduction of negative feedback control scheme, as much as possible for signal processing and the initial value of the necessary constraints to block for the control process, the relationship between real-time response speed, damping coefficient and steady-state error should be dealt with. Because most of the control process is dominated by the control hydraulic components, the steady-state error performance is the main object to solve in order to avoid the large influence of the non-linearity of hydraulic components on the system. Air compressor and other power source equipment, in order to cooperate scientifically with the driving equipment, carry out necessary classification processing, so that the damping coefficient of each small system is easy to get the best value.
4. Real-Time Guarantee of Drilling Rig Control System
In the modern rig control system, because the controlled object, measurement and control device and other physical equipment are more and more dispersed on the body, and the system scale is more and more complex, it is easy to realize the precise unmanned and intelligent operation function, and the problem of real-time becomes more prominent. In order to complete the control task, the information transmission in the system must arrive accurately within the specified communication time. How to reduce the arrival time according to the control requirements of the control object is the problem to be studied in real-time. The whole communication delay from the information transmission to the information reception is called the end-to-end communication delay. It mainly includes generation delay, queuing delay, transmission delay and sending delay. Modern rig control is characterized by absolute control of the stability of the entire system, which can allow the real-time reduction of several points of control to improve stability accuracy [4].

Specifically, the real-time control network is mainly related to the following aspects:

1) The hardware performance of the network itself, including the topology of the network, communication media, transmission rate of the network interface, and so on. The higher the transmission rate of the communication media, the faster the transmission rate of the network interface, and the higher the real-time performance of the network. In this project, the equipment with the lowest transmission rate of 250K baud rate is adopted [5].

2) Network communication protocol, including media access control mode, network communication protocol hierarchy, transmission reliability, connection control and so on. The simpler the hierarchical structure is, the higher the real-time performance of the system is. The Daisy chain of hard interrupts is used to deal with the logical relationship in the priority request-level events [6].

3) The amount of information on the network, also known as the load of the network, refers to the amount of information that the network needs to transmit in a certain period of time. Network transmission of information is less, because too much of nodes on the drilling rig, if all information, the network load is heavy, its unreliability in real time, using the master node to request information, from the node can send relevant information, implements the asynchronous communication service, reduce the network load, so as to improve system real-time performance [7].

4) By using the frame with priority short message for programming control, the meaning of the control information is realized by coding, so as to achieve the problem of real-time software operation [8].

Under the requirements of the following design, Jiangxi Dongrui Machinery Co., Ltd. carried out the non-standard design and production of the multi-function drilling machine.

5. Realization of Drilling Rig Control System
Under the premise of meeting the design function requirements, the multi-function drilling rig control system is designed and completed by Jiangxi Dongrui Machinery Co., Ltd. In the design and implementation of the project, we have received strong support from the State Grid Research Institute of Economics and Technology and other relevant cooperative units. We are grateful to the researchers of State Grid Research Institute of Economics and Technology and other researchers for assisting the project. Thanks to the support of the State Grid Corporation of China (5200-201956116A-0-0-00) R&D program: research on key technologies for designing micro-pile foundations in mountainous areas to realize the mechanized construction of UHV AC transmission lines, as shown in figure 3 and figure 4.
6. Conclusion

This paper designs a multi-function drilling rig control system to solve the following problems:

1) The control of all the key points realizes the closed-loop control.
2) All the components of the rig equipment to achieve electronic and digital, the whole machine to achieve full automation.
3) The real-time response of remote control is about 20ms, which ensures the stability and security of the control system.

In this paper, the multi-function drilling rig control system design and implementation; Solve the practical difficulties in the construction of the power industry project, ensure the safety of the construction personnel, convenient and fast, greatly improve the work efficiency, environmental protection and high efficiency of the project. There is still a lot of work to be done in the field of unmanned drilling RIGS.

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