Opinion Article

A Review of Integrated Control Technology of Tension Stringing Equipment in Transmission Line Erection

ABSTRACT

The research status and progress of the integrated control technology of tension stringing equipment in transmission line erection, mainly reflected in online monitoring and intelligent control system, nonlinear control strategy, fuzzy logic control strategy, neural network control strategy and so on. These technologies have important roles and values in improving the operation efficiency and reliability of tensioning equipment, reducing construction cost and risk, ensuring the quality and safety of line erection and so on. Such as improving the coordination and compatibility of each subsystem of tensioning equipment, developing more advanced, intelligent, flexible, robust, adaptive, energy-saving and environmentally friendly control strategies and algorithms, developing more concise, efficient, stable, reliable, safe, easy-to-use, easy-to-maintain, easy-to-expand and easy-to-integrate control systems and so on, are more worthy of thinking for future researchers.

Keywords: Tension stringing equipment;integrated control technology;nonlinear control strategy;fuzzy logic control strategy;neural network control strategy.

1. INTRODUCTION

Tension stringing equipment refers to the puller and tensioner used in the construction of transmission lines. The puller is used to pull the conductor along the tower arrangement, and the tensioner is used to apply a certain tension to the conductor to make it reach the specified tightness. The control technology of tension stringing equipment is an important factor affecting the quality and efficiency of transmission line erection, which involves the coordinated control of multiple subsystems such as puller, tensioner, conductor and so on, as well as the precise control of state parameters such as conductor tension, speed, position and so on. With the rapid development of China's economy and society, the demand for electricity is increasing, and the power grid construction is facing unprecedented challenges.

According to the China Electric Power Development Report 2020, China's total electricity consumption reached 7.14 trillion kWh in 2019, an increase of 4.5% year-on-year, of which industrial electricity consumption accounted for 67.5%. To meet the electricity demand of various regions, industries and levels, China's power grid construction scale is expanding, and the total length of transmission lines reaches 1.206 million kilometers. To improve the quality and efficiency of power grid construction, State Grid Corporation of China proposed the "intelligent, digital and platform" construction development strategy, requiring the extensive application of information technology, communication technology, automation technology and other modern scientific and technological means in transmission line erection, to achieve intelligent management and control of the construction process. Integrated control of tensioning equipment is an innovative technology that meets this strategic requirement and has important application value in transmission line erection.

This paper aims to review the research status of integrated control of high-voltage line tensioning equipment, focusing on the various control strategies and systems that have been developed and implemented, as well as their roles in improving machine performance and safety. This paper also analyzes the problems and challenges in this field, and proposes possible future development directions and prospects. The structure of this paper is as follows: The first part introduces the research status and progress of online monitoring and intelligent control system of tensioning equipment; The second part introduces the main control strategies and methods of integrated control of tensioning equipment; The third part introduces the main control systems and structures of integrated control of tensioning equipment; The fourth part introduces the development direction and challenge of integrated control technology of tensioning equipment; The fifth part gives the conclusion and prospect of integrated control technology of tensioning equipment.

2.ONLINEMONITORINGAND INTELLIGENT CONTROL SYSTEM OF TENSIONING EQUIPMENT

This is a method that uses network, controller, state monitoring, signal processing and other technologies and theories to remotely control and monitor the tensioning equipment, realize the collection and control of the main working state of the tensioner, and real-time monitoring and control. This method can improve the operation efficiency and reliability of the tensioning equipment, reduce manual intervention and misoperation, and reduce construction cost and risk. At present, many research achievements have been made in this aspect. For example, Wang Shiyang et al. [1] designed a remote control system for power grid tensioning equipment based on intelligent control, analyzed the main characteristics of power grid tensioning equipment data, processed the data in power grid tensioning equipment by adaptive wavelet denoising method, and effectively eliminated the noise and oscillation phenomenon of the equipment. The system not only has good data preprocessing ability, but also has fast response speed and high precision control results. Li Yuanming [2] designed SAQ-250 traction machine remote controller, which can realize remote control of traction machine, reduce the safety risk of operators, and play a certain role in promoting the development of tensioning equipment. Liu Jianfeng et al. [3] studied the integrated system of intelligent tension field control, which promoted the gradual development of transmission and transformation tension line construction equipment and emergency equipment to the direction of serialization, standardization and matching. Qiu Churan [4] researched and developed a remote intelligent control system for line erection tensioner, which improved the disadvantage of unstable tension in line erection process by applying network, controller, state monitoring, signal processing and other technologies and theories. The system is divided into two parts: vehicle terminal and remote monitoring center, which realizes the collection and control of the main working state of the tensioner, as well as real-time monitoring and control. The remote monitoring system can realize the control of line release of tensioner, adjust the working state of tensioner, complete safety braking and alarm functions. Gao Youliang et al. [5] designed a remote state monitoring system for tensioning equipment based on multi-scale convolution network. The system realized the hardware execution environment by setting terminal processor and wireless communication module. In software aspect, the software execution environment was realized by protocol porting processing and serial communication subroutine. The experimental results show that the monitoring system can effectively reduce the difference between valley electricity degree, flat electricity degree value of tensioning equipment and standard electricity output result, which plays a big role in maintaining the long-term stable work of equipment structure. Hong Qiaozhang carried out a research on intelligent upgrading of automatic control of tensioner, and proposed a low-risk, high-efficiency and high-economic technology route. Hou Jianming et al. [6], developed a “tensioner collaborative intelligent control system”, which combined double position and wireless video monitoring system, etc., connected by Profibus bus, applied to transmission line conductor tension laying construction, could transmit data within 50m range, thus achieving remote control goal.

This part introduces the research status and progress of online monitoring and intelligent control system of tensioning equipment, which shows that this method has advantages in improving operation efficiency and reliability of tensioning equipment, reducing manual intervention and misoperation, reducing construction cost and risk.

3.MAIN CONTROL STRATEGIES AND METHODS OF INTEGRATED CONTROL OF TENSIONING EQUIPMENT

3.1Control Strategies Based on Nonlinear Control Technology

Nonlinear control technology refers to the control methods that design and implement effective, stable, robust and reliable performance indicators for nonlinear dynamical systems, such as feedback linearization, variable structure control, adaptive control and so on. Nonlinear control technology has the advantage of overcoming the nonlinear characteristics and uncertainties of the system, and realizing the precise tracking and adjustment of the system state and output in the integrated control of high-voltage line traction and tensioning machine. This method can improve the dynamic response and anti-interference ability of the tensioning equipment, reduce the fluctuation and overshoot of the line tension, and ensure the quality and safety of the line erection. At present, many research achievements have been made in this aspect. For example, Li Xiaofeng et al. [7] proposed an integrated control scheme for high-voltage line traction and tensioning machine based on feedback linearization and adaptive sliding mode variable structure control, which transformed the dynamic model of high-voltage line traction and tensioning machine into an affine system, and used adaptive sliding mode variable structure controller to compensate for system uncertainty and external disturbance, and realized the coordinated control of each subsystem of high-voltage line traction and tensioning machine (such as traction machine, tensioner, conductor, etc.). The scheme verified its effectiveness and robustness by simulation and experiment, which can ensure that the high-voltage line traction and tensioning machine can achieve the expected goal in the line erection process, and improve the safety of the line erection. Hany et al. [8] proposed a nonlinear dynamic controller based on the nonlinear dynamic model of wire rope tensioner and puller. This controller can accurately adjust the tension of the wire, while allowing the machine to run at high speed, without any obvious overshoot. Tao et al. [9] used PID controller to adjust the wire tension during high-voltage wire traction. The design of this controller is to ensure the smooth and accurate transmission of power. Wang Xiaodong et al. [10] proposed an integrated control scheme for high-voltage line traction and tensioning machine based on feedback linearization and neural network adaptive estimator, which transformed the dynamic model of high-voltage line traction and tensioning machine into an affine system, and used neural network adaptive estimator to estimate system uncertainty and external disturbance, and realized the coordinated control of each subsystem of high-voltage line traction and tensioning machine (such as traction machine, tensioner, conductor, etc.). The scheme verified its effectiveness and robustness by simulation, which can ensure that the high-voltage line traction and tensioning machine can achieve the expected goal in the line erection process, and improve the safety of the line erection.

3.2 Control Strategies Based on Fuzzy Logic

Fuzzy logic is a mathematical method to deal with uncertainty and fuzziness, which can be used to describe human thinking and language expression. Fuzzy logic has the advantage of handling the imprecision and complexity of the system, and realizing the flexible adjustment of the system state and output in the integrated control of high-voltage line traction and tensioning machine. This method can improve the adaptability and fault tolerance of the tensioning equipment, reduce the dependence on system parameters and environmental conditions, and ensure the quality and safety of the line erection. At present, many research achievements have been made in this aspect. For example, Zhu et al. [11] proposed a control strategy based on fuzzy logic to control the speed and tension of the wire. The design of the fuzzy controller is to adjust the speed of the wire traction and tensioning machine according to the measured tension, to ensure the smoothness and accuracy of the tensioning process. For the same purpose, Shojaei et al. [12] proposed a control strategy based on empirical ratio. This strategy used the ratio of tensioning speed and wire traction speed to accurately adjust the tension in the wire.

This part introduces the main control strategies and methods of integrated control of tensioning equipment, which shows that these control strategies have advantages in overcoming the nonlinear characteristics and uncertainties of the system, handling the imprecision and complexity of the system, and realizing the precise tracking and flexible adjustment of the system state and output.

4. MAIN CONTROL SYSTEMS AND STRUCTURES OF INTEGRATED CONTROL OF TENSIONING EQUIPMENT

In addition to the development of control strategies, several control systems have been developed to realize the integrated control of high-voltage line traction and tensioning machine. These control systems usually consist of hardware and software parts, the hardware part includes actuators, sensors, communication modules, data acquisition cards, etc., the software part includes control algorithms, data processing, human-machine interface, etc. These control systems can realize the integrated control of each subsystem of the tensioning equipment, as well as the real-time monitoring and control of the state parameters such as wire tension, speed, position, etc. These control systems can improve the intelligence and automation level of the tensioning equipment, and enhance the efficiency and quality of the line erection. At present, many research achievements have been made in this aspect. For example, Lee et al. [13] proposed a hybrid control system for wire tensioning. This system combines the traditional proportional-integral-derivative (PID) controller with the fuzzy logic controller to ensure accurate control and stable wire tension. Similarly, Chen et al. [14] developed a closed-loop control system for wire tension that combines PID controller and fuzzy logic controller. Using fuzzy logic controller, the speed of the traction line machine is adjusted according to the measured tension. Recently, some researchers have developed control systems using advanced technologies such as artificial neural networks (ANNs) to realize the integrated control of high-voltage line traction and tensioning machine. Wang et al. [15] proposed a neural network-based wire traction and tensioning control system. This system uses neural network to predict the wire tension response and adjust the traction speed accordingly. Similarly, Zhao et al. [16] proposed a control system that uses neural fuzzy network to adjust the wire tension. This system can achieve high accuracy in controlling wire tension.

This part introduces the main control systems and structures of integrated control of tensioning equipment, which shows that these control systems have advantages in realizing the integrated control of each subsystem of tensioning equipment, as well as the real-time monitoring and control of state parameters such as wire tension, speed, position, etc.

5. DEVELOPMENT DIRECTION AND CHALLENGES OF INTEGRATED CONTROL TECHNOLOGY OF TENSIONING EQUIPMENT

The integrated control technology of high-voltage line traction and tensioning machine is the key technology in the line erection construction, which directly affects the quality and efficiency of the line erection. With the continuous expansion of the power grid construction scale and the continuous change of the line erection construction conditions, higher requirements and greater challenges are put forward for the integrated control technology of high-voltage line traction and tensioning machine. In order to adapt to these requirements and challenges, the integrated control technology of high-voltage line traction and tensioning machine needs to be further developed in the following aspects:

Improve the coordination and compatibility among each subsystem of the tensioning equipment, and realize the optimization and improvement of the overall performance of the tensioning equipment. This requires in-depth research and standardization on the dynamic models, parameters, interfaces, communication protocols, etc. of each subsystem of the tensioning equipment, so as to realize the seamless connection and collaborative work among each subsystem.

Develop more advanced, intelligent, flexible, robust, adaptive, energy-saving and environmentally friendly control strategies and algorithms, and realize the precise tracking and adjustment of each state parameter of the tensioning equipment. This requires using advanced technologies and methods such as artificial intelligence, machine learning, optimization theory, control theory, etc., to design control strategies and algorithms that can adapt to complex and variable construction environments and conditions, can deal with system uncertainty and disturbance, can achieve optimal or suboptimal system performance indicators, can reduce system energy consumption and emission.

Develop more concise, efficient, stable, reliable, safe, easy-to-use, easy-to-maintain, easy-to-expand and easy-to-integrate control systems, and realize the integrated management and monitoring of each functional module of the tensioning equipment. This requires using modern information technologies such as embedded systems, Internet of Things technology, cloud computing technology, big data technology, etc., to build a control system platform with high performance, low cost, high reliability, high safety, high availability, high maintainability, high scalability and high integrability.

Develop more practical, convenient, friendly, intuitive, interactive, intelligent, personalized and diverse control system human-machine interfaces, and realize intelligent operation and visual monitoring of the tensioning equipment. This requires using human-machine interaction technologies such as virtual reality technology, augmented reality technology, voice recognition technology, image recognition technology, etc., to design a control system human-machine interface that conforms to human cognitive rules and operation habits, has good user experience and user satisfaction, can provide various information feedbacks And interactive methods, can be personalized according to user needs and preferences.

Develop more advanced, comprehensive, accurate, real-time, fault diagnosis, fault warning, fault recovery, self-learning, self-optimizing control system monitoring and fault diagnosis systems, to achieve intelligent maintenance and guarantee of tensioning equipment This requires using intelligent monitoring and fault diagnosis technologies such as sensor network technology , data mining technology , fault diagnosis technology , etc., to build a control system monitoring and fault diagnosis system that can monitor and analyze each component and state of tensioning equipment comprehensively , accurately , real-time , can timely detect and identify system abnormalities and faults , can provide effective fault warning and fault recovery solutions , can self-learn and self-optimize according to system operation data . This part introduces the development direction and challenges of integrated control technology of tensioning equipment.

This part also points out some problems and challenges faced by these directions, such as dependence on system parameters and environmental conditions, complexity of system structure and function, lack of system monitoring And fault diagnosis.

6. CONCLUSION

This paper reviews the research status of the integrated control technology of tensioning equipment for high-voltage line erection, and introduces the research achievements in three aspects: online monitoring and intelligent control system of tensioning equipment, control strategy based on nonlinear control technology, and control strategy based on fuzzy logic, as well as their roles in improving machine performance and safety.

This paper also analyzes the problems and challenges in this field, and proposes the development directions in improving the coordination and compatibility among each subsystem of the tensioning equipment, developing more advanced, intelligent, flexible, robust, adaptive, energy-saving and environmentally friendly control strategies and algorithms, developing more concise, efficient, stable, reliable, safe, easy-to-use, easy-to-maintain, easy-to-expand and easy-to-integrate control systems, developing more practical, convenient, friendly, intuitive, interactive, intelligent, personalized and diverse control system human-machine interfaces, developing more advanced , comprehensive , accurate , real-time , fault diagnosis , fault warning , fault recovery , self-learning , self-optimizing control system monitoring and fault diagnosis systems.

This paper provides a valuable reference for researchers and engineers in this field, and also provides some inspiration and suggestions for future research or exploration in this field.

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