Study on Live Overhaul Robot Technology for Substation

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Keywords: Live Overhaul; Robot; Substation Automation; Master-Slave Control

Abstract. The automation and intelligence of the overhaul technology are related to the level of the whole substation automation and intelligence. Aiming at the problems of low automation level of substation high-voltage equipment overhaul, this paper mainly studies robot-based live overhaul technology. The design for robot system is completed and the function test for live overhaul is finished. Besides, the work efficiency and reliability are enhanced.

Introduction

Intelligent substation is an important foundation and support for the strong and smart grid, and equipment information digitization, function integration, compact structure and state of overhaul are the development direction of the substation. All of this is to ensure that the substation keeps reliable and stable operation. However, the automation and intelligent of the overhaul technology of the equipment are rarely mentioned.

In order to improve the automation level of substation equipment overhaul, this paper studies how to realize live overhaul technology for substation high-voltage equipment by utilizing new technology and equipment like sensor, detection equipment and special mechanical arm carried by robot. The research on live overhaul robot technology for substation is very important for improving the reliability and the automation and intelligence of the power supply.

Live overhaul principle of robot

Working Regulations of State Grid Corporation of China on Electric Power Security (Power Transformation) (hereafter referred to as Security Regulations for short) (version of 2009) stipulates in 4.2.2, “When the maintenance device has power outage, all power sources should be completely disconnected. Operation on equipment whose power source is disconnected only through circuit breaker (switch) is prohibited. The disconnecting switch (disconnecting link) must be pulled open, and all aspects should have an obvious cut-off point. If the cut-off point of power failure equipment cannot be observed, electrical and mechanical indexes that can reflect equipment operation conditions must be seen.” However, in the future, there is no conventional disconnecting switch between high-voltage bus and disconnecting circuit breaker in the smart substation. During the transformers and other equipment overhaul, the connection fittings between the bus and the disconnecting circuit breaker should be disconnected, in order to creat an obvious cut-off point. Therefore, disconnecting the connection fittings is the premise of overhaul.

In this paper, the robot can loosen the anchor screw on the fitting between disconnecting circuit breaker and bus through the paw on the mechanical arm, so as to cut off the connection between disconnecting circuit breaker and bus. Thus an obvious and visible breaking point will appear. This will guarantee the safety of maintenance personnel. The fitting structure is presented in Fig. 1.

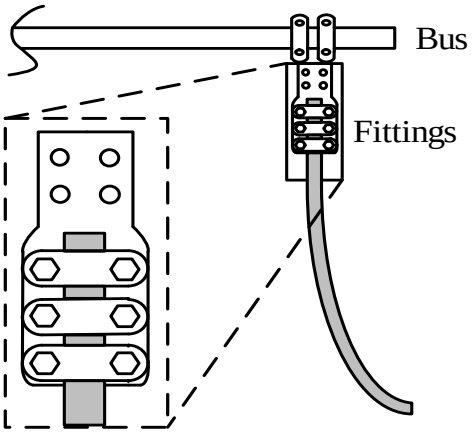

Fig.1. Fitting structure

After achieving isolation between the overhaul equipment and the bus by disconnecting the fittings, the robot with advanced detection equipment and mechanical hand will be able to further overhaul for the equipment. The concrete realization of the robot overhaul technology is described in detail through taking off the fittings in this paper.

Realization of robot overhaul technology

Robot is mainly composed of truck carrier, control room, lifting platform, master-slave mechanical arm, insulation system, display system and electronic control system. Here, master-slave mechanical arm, visual system and electronic control system are mainly introduced. The robot system is shown in Fig. 2.

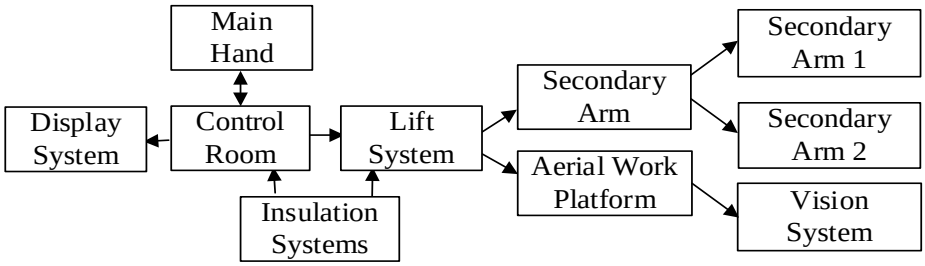

Fig.2. Robot system chart

Realization of mechanical arm operation. The robot adopts the operation mode of master-slave mechanical arm. The operating personnel will be located in the control room on the ground and conduct remote operation for the slave manipulator according to data provided by the visual system of robot, so as to complete fitting disconnection. The slave manipulator of robot adopts the operation mode of two 6-DOF robotic manipulators with totally the same structure. In this way, the robot can realize flexible operation in the three-dimensional space. Meanwhile, the slave manipulator can realize force reflecting tele-presence of operating personnel on the ground by way of force feedback through the force sensor. In this way, the personnel can perceive the real operating environment of slave manipulator and make a correct decision according to this. The master manipulator adopts a mechanical structure the same with that of slave manipulator, and applies joint – joint driving mode.

The lifting insulation arm of robot will rise to the height of the fitting from the mechanical arm (generally speaking, the height of 110kV bus to the ground is 5-6m). In the control room on the ground, the master manipulator movement conducted by the operating personnel is measured through the potentiometer at the joint, and the position signal obtained will be sent to the controller. The controller will send movement instructions to the slave manipulator after calculation, so as to realize position control for the slave manipulator. Besides, the operating personnel can accurately control the position of the paw of slave manipulator through visual system. One slave manipulator paw will firmly grasp the fixed end of bolt on the fitting, and the other slave manipulator paw will rotate the nut. During the movement and execution process of slave manipulator, the reactive force

borne by the slave manipulator will be detected by the joint force sensor of slave manipulator and sent to the controller. The controller will send the force signal to master manipulator after calculation, and electric current change of torque motor in the master manipulator will generate joint torque which can act on human hand finally. Thus force reflecting tele-presence is realized. Men can make a decision according to the force feeling received by human hand, and then operate the master manipulator. The master manipulator is close to the slave manipulator, and the position control for slave manipulator and force gained by human hand are fed back at the same time. Therefore, position and movement of slave manipulator and rotation of paw are accurately controlled through visual system and force feedback system in the whole process.

Visual system. Four high-definition camera terminals distributed on the aerial work platform will complete video capture. Mpeg4 real-time compression is conducted for video data; real-time display is realized for video data by utilizing multiple screens (high-definition display screen) in the monitoring center, and the video data are saved. The system adopts Client/Server structure based on TCP/IP and Server program is located at the camera terminal. The video capture range is ±180º at horizontal direction and -60º ~+90º at pitching direction; the video quality is not lower than 20 frames / second. Operating personnel in the control room on the ground can make a right judgment through this visual system. Besides, remote control is realized for the slave manipulator through master manipulator, and accurate execution can be conducted.

Electrical control system. The electrical control system structure is presented in Fig. 3. In the control room, position signal measured by potentiometer of master manipulator will be directly sent to the master controller, and the master controller will send out instructions after calculation. The instructions will be sent to the sub-controller on aerial work platform, and the sub-controller will transfer the instructions to the slave manipulator for execution after calculation, so as to complete the control for slave manipulator DOF.

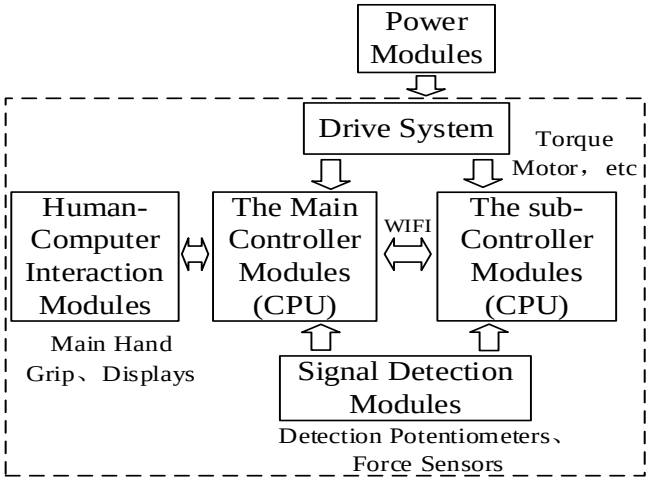

Fig.3. Electrical control structure chart

Meanwhile, signal measured by force sensor of slave manipulator will also be sent to the master controller through wireless communication after calculation of the sub-controller, and applied to the torque motor of master manipulator after calculation of the master controller, so as to realize force feedback. In electrical control, all movements of the robot are repetitions of this process.

Electromagnetic immunity and insulation. Electronic equipment of robot adopts the form of metal shell (or non-metal shell containing metal net), so as to prevent the strong electromagnetic environment of transformer substation from affecting normal operation of equipment inside the robot. High-voltage line and high-voltage equipment mainly generate radio disturbance in the frequency band of 0.15~30MHz and the frequency band of secondary equipment for power protection is often within KHz. The frequency band of wireless communication adopted by robot is 2.4 GHz, so neither fundamental wave nor higher harmonic will disturb each other, which can meet the wireless communication management standards of transformer substation.

When the robot disconnects the fittings between disconnecting circuit breaker and bus, it might bear the action of temporary overvoltage, switching overvoltage and maximum working voltage.

The insulation system is composed of automobile ground insulation support and lifting insulation arm. Robot insulation design of hot-line work aimed at different voltage classes is relatively mature and reliable, so unnecessary details will not be given in this paper.

Functional test and experiment

In the laboratory, disconnection and overlapping joint tests are conducted for fittings at a certain height via robot. The mechanical arm rises to the height of fittings under the control of operating personnel. In virtue of visual system, one slave manipulator is made to fix a certain bolt on the fitting through remote control for master manipulator, and the other slave manipulator loosens this nut by rotating the paw with special spanners. After the nut is separated from the bolt, the nut and bolt are collected to a specific position on the mechanical arm. When the operating personnel repeatedly loosen the nut after getting familiar with the whole robot system, the time consumed will become shorter and shorter. Finally, the disconnection and overlapping joint tests can be completed smoothly.

In the whole process, only 1-2 operators are required to complete disconnection (overlapping joint) for the fittings and the whole process takes about 20 minutes. Compared with the existing manual methods, it has improved man efficiency. From the operation experience of operating personnel, the force reflecting tele-presence feedback system of master manipulator has greatly improved the operation experience and made the operation more “interactive”. From the aspect of execution accuracy and veracity, the operating personnel can comprehensively observe the positions of working arms without any dead angle via multi-screen display system. In this way, a reasonable decision can be made, and the operation reliability and security will be increased.

Conclusion

Live robot technology for substation is designed and robot sample is processed. Besides, experimental test is completed, and the experiment shows that the designed robot can pass the function test of disconnecting fittings well. The disconnection efficiency, success rate and security coefficient are increased. The robot can provide great help for the overhaul of high-voltage switch and control equipment in the substation, and even completely replace the manual, which is of great significance to promote the automation and intelligent of power grid.

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