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Design of Robotic Automation System for Power Inspection

Xin ZHENG[a,1], Junyi SHI[a] and Haihua ZHANG[a]
[a]*State Grid Jiangsu Electric Power Co., Ltd, Extra-High Voltage Branch Company, Nanjing 211102, China*

Abstract. In order to solve the problem of high leakage rate in the existing automatic control system of electric power inspection robot, the automatic system of electric power inspection robot was proposed. The hardware design of the automatic control system of the power inspection robot is embedded Linux design, motor driver design and infrared thermal image thermometer design; The software design includes motor driver initialization, motion control programming, interrupt positioning and calibration programming. Through the design of system hardware and software, the operation of the automatic control system of power inspection robot based on embedded Linux is realized. The experimental results show that the leak detection rate of the designed system is far lower than that of the existing system, and its minimum value can reach 10.25%. Conclusion: Compared with the existing automatic control system of electric power inspection robot, the designed automatic control system of electric power inspection robot greatly reduces the rate of missed inspection, which fully shows that the designed automatic control system of electric power inspection robot has better performance.

Keywords. Embedded Linux, Power patrol inspection, Patrol robot, control

1. Introduction

The continuous progress of science and technology, the deepening of the power system reform, the national power grid development support, the degree of automation of the power system has been continuously improved, substation inspection work also gradually tends to be unmanned or less humanized [1]. The normal work of the substation equipment is related to the safe production and safe operation of the entire substation, so it is necessary for the staff to carry out regular daily inspection tasks on the substation operating equipment, collect the operating data of the equipment and analyze it. Due to the large workload, the staff's technical level is not uniform, and the degree of seriousness of the work is not consistent, so the daily inspection and maintenance of the substation cannot be fully guaranteed, and sometimes even cannot find the abnormal condition of the equipment, and cannot deal with the problem in time, which may cause great losses [2]. In order to solve such problems, according to the actual situation of electric power, combined with the traditional inspection method, while taking into account the work mode of the substation and the development of inspection robot application technology, substation inspection robot into the research and adaptation of the application stage [3]. Substation inspection robot using outdoor work, assist or

[1] Corresponding Author: Xin ZHENG, 201961204209@njtech.edu.cn

replace the staff of the substation equipment inspection work. Substation inspection robot is a kind of mobile robot, can in the case of unmanned or less people, the use of image processing and pattern recognition and other technologies, real-time monitoring of substation high-voltage equipment, and its operating conditions for analysis, can greatly improve the substation equipment condition monitoring accuracy, real-time as well as the level of automation, with a broad application prospect [4].

The motion control system of the substation inspection robot is an automatic control system that takes the robot's motion position and speed as the control object of the whole system, which is also called a follower system [5]. Specifically, the motion control system is based on the automatic control theory, with a high-performance motion controller as the core, through the power electronic power change device composed of actuators to realize the control of the motor. Substation inspection robot movement accuracy is directly determined by the performance level of the entire motion control system, therefore, in the substation inspection robot research, the robot's autonomous positioning technology is the most critical, only to ensure that the robot's positioning accuracy under the premise of the inspection robot in order to carry out substation equipment inspection and other tasks [6].

This paper will mainly the drone tilt photography technology for three-dimensional real model and highway BIM model as the carrier of construction progress monitoring data, using the construction progress analysis based on the secondary development of MicroStation platform plug-in, through the boolean algorithm fast 3 d real model and highway BIM model matching, segmentation and calculation, get the construction progress report. The construction progress analysis plug-in obtains the actual construction progress of the project in K114 + 700 to K116 + 200 section of a highway project, and compares the actual construction progress with the planned construction progress, finds out the construction progress deviation, and corrects it in time, so as to realize the automatic monitoring of the highway construction progress.

2. The Research Methodology

2.1. System Requirements Analysis

The substation inspection robot system is physically divided into the ground station system centered on the industrial computer and the mobile station system centered on the on-board computer (substation inspection robot body) [7]. The main purpose of the ground station system is to display the robot's speed, position and other status information and alarm information, to realize the remote real-time monitoring of the mobile station; instrumentation image recognition and detection; remote inspection tasks to the inspection robot. The main work of the mobile station is to transmit the infrared thermal image and visible light image collected by the PTZ to the ground station; to transmit the sound status of the substation equipment collected and analyzed to the ground station; to transmit the movement status of the body to the ground station, and according to the data of LIDAR and ultrasonic sensors, it can realize the automatic path planning and inspection. Image and state transmission and motion control is the main function of the mobile station, the ground station and the robot to wireless bridge way to realize the communication, the robot will be collected by the PTZ image information and inspection robot state information through the wireless bridge to the ground station; inspection robot to realize straight line walking and turning and other changes in different motion states are through the motion control system, so that the motion control system for the substation inspection robot actuator, which consists of the laser radar sensor and other data, to achieve automatic path planning and inspection. The actuator of the robot consists of controllers, drivers, motors, speed reducers, encoders and mechanical parts, etc. By analyzing the motion commands given by the ground station, it completes the speed control of each driving wheel, thus completing different motion actions.

Wheeled robot is a complex system with large delay and high nonlinearity [8]. In order to make the motion control system of the substation inspection robot developed in this paper has the function of fully autonomous movement, can realize its smooth movement, and has a certain load capacity. Therefore, the motion control system mainly completes the control of the motor, adjusts the running speed and direction of the left and right-side motors, and realizes the mobile function of the inspection robot, with the following design requirements.

- The entire motion control system has to be mounted on the robot with the smallest possible size and weight, and easy to install.
- As far as possible to achieve modularity, scalable, easy to follow the increase in functional modules.
- Real-time.
- Friendly human-machine interface, convenient for system debugging and monitoring.
- The motion of the robot is realized by the coordinated motion of the wheels on both sides, and real-time and accurate control is the prerequisite for realizing the coordinated motion of the robot.
- Balanced control, the robot should have a certain degree of resistance to interference, such as stable operation on slightly uneven ground.
- (b) Fine-tuning, where the inspection robot collects information by means of photographs, infrared or sensors, and the motion control system should be capable of fine-tuning the chassis so that the robot is in the optimal position to acquire the information.
- Have a certain degree of fault tolerance, when the robot movement of certain abnormalities, the motion control system should be able to make a certain degree of processing according to the need [15].

2.2. The Hardware Design of the Automated Control System of the Electric Power Inspection Robot

2.2.1. Embedded Linux Design

Embedded Linux is the main controller of the power inspection robot. According to the needs of the design system, myRIO-1900 embedded Linux from NI company is selected as the main controller of the design system. The myRIO controller is embedded with Xilinx Zynq chip, which has strong processing and computing performance.

MyRIO-1900 embedded Linux is a controller that can be repeatedly configured and used. It has the advantages of simple to use, simple programming and development, carrying rich on-board resources, DC power supply, etc., and can well realize the control of power inspection robots [16].

2.2.2. Motor Drive Design

As the executive element of the motion control system, servo motors and stepper motors are the most widely used. Both in the control mode on the use of pulse signal control, but the performance parameters and application environment is still very different, the system uses the servo motor, mainly from the following aspects to consider: servo motor precision is better than the stepper motor; low-speed operation will not appear low-frequency vibration phenomenon; its overload capacity is much greater than the stepper motor; will not appear “lost step” phenomenon [9].

The motor driver is the key part of the design system, and its main function is to provide power. In addition, the motor driver has a braking function, which can support the power inspection robot to stop stably in the slope section and prevent the occurrence of accidental slipping.

The motor drive performance parameters are shown in Table 1.

Table 1. Performance parameter table of the motor driver.

the name of the performance parameter	**Values**	**Unit**
Voltage	24	V
Rated power	200	W
No-load speed ,	3 500	RPM
No-load Current, No-load Current, No-load Current, No-load Current	<0. 8	A
Load speed	3 000	RPM
Load torque	0. 64	N. m
Reducer ratio	15 : 1	—

The motor driver is equipped with a DC brushless motor, the motor driver has a wealth of pins, specific definitions as shown in Table 2.

Table 2. Motor Driver Pin Definition Table.

interface type	**pin names**	**Definition Note**
control signals	GND	Signal ground
	ALM	Alarm output
	PG	Hall Signal Abnormal Output
	FR	Motor direction control
	EN	Enable Signal
power end	W	Motor phase wires
	V	Motor phase wires
	U	Motor phase wires
	VDC	Power input
Hall signal input	GND	Hall powered
	HA	Hall Signal
	HB	Hall signals
	HC	Hall signals

2.2.3. Infrared Thermal Imager Thermometer Design

The power inspection robot needs to measure the surface temperature of the target, which requires that the power inspection robot can complete the temperature detection without touching the target. Infrared temperature measurement has the advantages of fast response time, long life and high security. Therefore, infrared thermal imager thermometer is selected to measure the target temperature. According to the actual requirements of the design system, the optris PI 400 infrared thermal imager thermometer of Opriz is selected.

The optris PI 400 infrared thermal imager thermometer has a small volume, a measurement speed of 80 Hz, an optical resolution of 382X288 pixels, a thermal sensitivity of 40 Mk, a temperature measurement range of [- 20900] degrees Celsius, and a spectral range of [7 5, 13] μ m. It can provide thermal imaging images in real time.

In the design system, the infrared thermal imager thermometer is connected to the switch inside the power inspection robot through USB cable, and then the measured data is uploaded to the upper computer through the router, and the generated image is displayed in the upper computer to achieve the temperature measurement function.

The above process realizes the hardware design of the automation control system of the power inspection robot, but it cannot realize the automation control of the power inspection robot, for this reason, the design of the system software part.

2.3. Power Inspection Robot Automation Control System Software Design

2.3.1. Initialization of the Motor Driver

Motor drive mainly exists in three control modes, respectively, position mode, speed mode and current mode, the design system uses the speed control mode. To this end, the motor drive needs to be initialized configuration, motor drive initialization process shown in Figure 1.

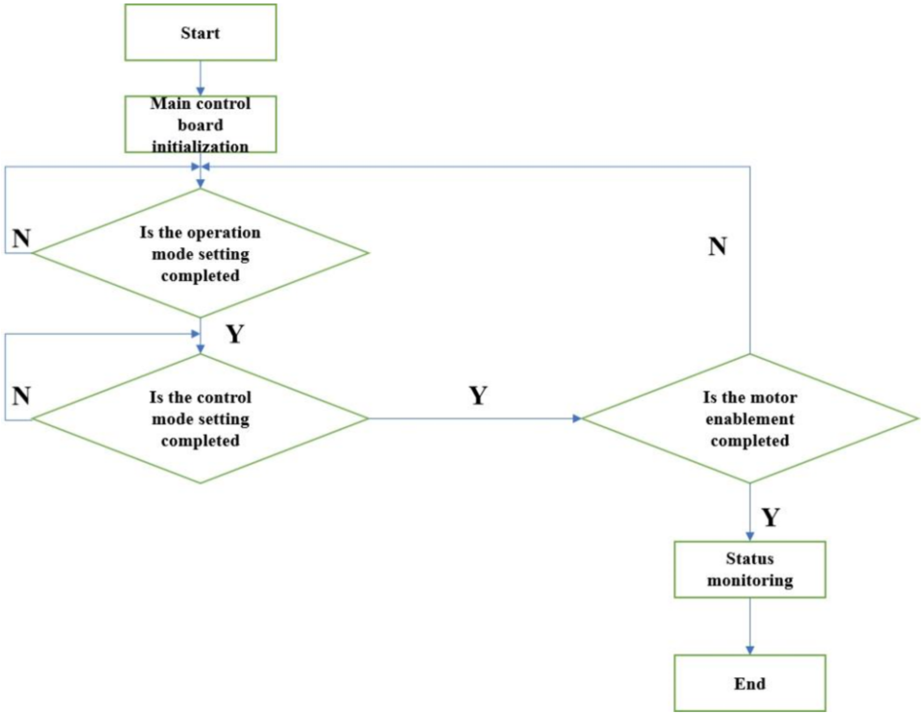

Figure 1. Flowchart of motor driver initialization.

2.3.2. Motion Control Program Development

In the automated control system of power inspection robot, the motor motion control program is the core of the system [10]. The motor motion control module uses four timers. Through the cooperation of 4 timers, not only can improve the smoothness of motor movement, but also can shorten the speed change process time. In the acceleration phase of the motor, the consumption time, instantaneous speed and displacement are expressed in the following equation (1).

$$\begin{cases} t_1 = \frac{A_{set}}{J_{set}} \\ V(t) = V_0 + \frac{1}{2} J_{set}\, t^2 \\ S1 = \int_0^{t_1} \left(V_0 + \frac{1}{2} J_{set}\, t^2 \right) dt = V_0 t_1 + \frac{1}{6} J_{set}\, t^3 \end{cases} \tag{1}$$

Among them.$t_1$denotes the time consumed during the acceleration phase of the motor and A_{set} Indicates the set acceleration value; and J_{set} indicates the set acceleration value; , , and $V(t)$ indicates the time of day$t$ the instantaneous velocity of; , , and V_0Indicates the initial speed of the setting; and $S1$ represents the displacement of the acceleration process. Then the motor motion control logic diagram is shown in Fig. 2.

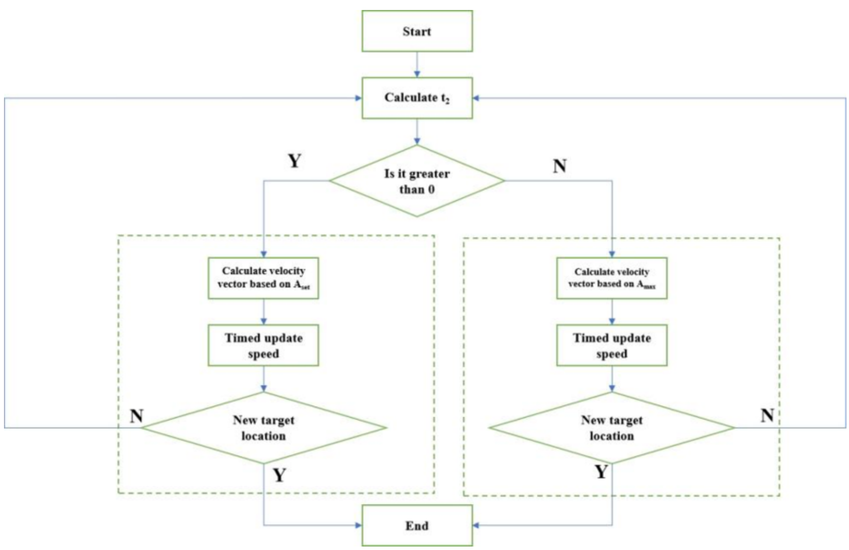

Figure 2. Logic diagram of motor motion control.

2.3.3. Interrupt Location and Calibration Procedure Development

Power inspection robot in the operation process, easy to accumulate errors, interrupt positioning and calibration program is the main function of eliminating the above errors.

The interrupt positioning and calibration program is shown in Figure 3.

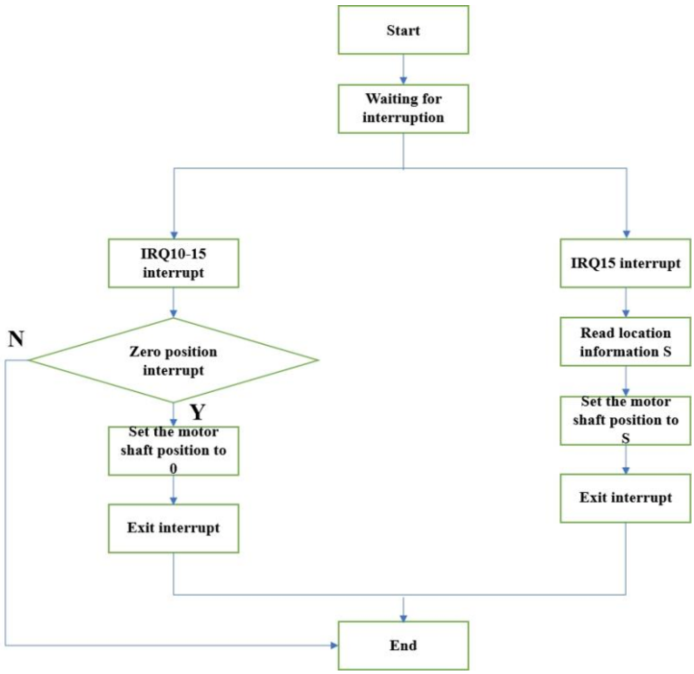

Figure 3. Diagram of interrupt localization and calibration procedure.

As shown in Figure 3, in the process of interrupt positioning and calibration, the real-time requirements of the program are high. When the power inspection robot runs at 1 m/s, 10 ms time indicates that the power inspection robot has run for 1 cm. Therefore, the program is set as the highest priority to ensure that the program can be executed in time.

Through the above system hardware and software design, the operation of the automatic control system of the power inspection robot based on embedded Linux is realized, providing more effective guarantee for the safe and stable operation of the power system.

3. Analysis of Results

In the above process, the design and operation of the automatic control system of the electric power inspection robot based on embedded Linux have been realized, but it is still uncertain whether it can solve the problems existing in the existing system. Therefore, a simulation comparison experiment is designed, and the existing system and the design system are used to carry out a comparison experiment to reflect the performance of the system through the leakage rate.

The comparison of the leakage rate obtained from the experiment is shown in Fig. 4.

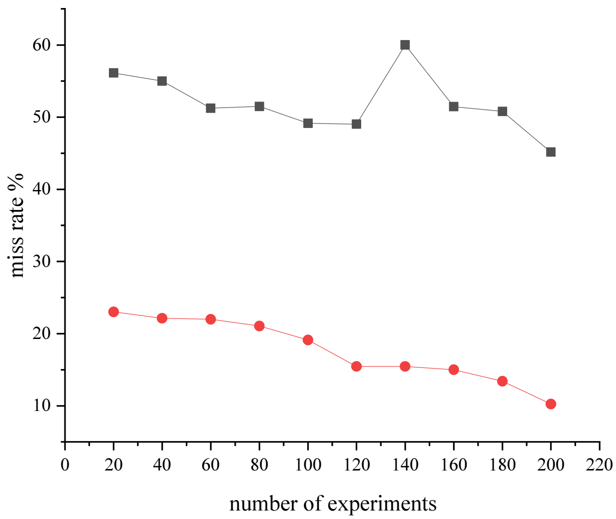

Figure 4. Comparison of leakage rates.

As the data in Fig. 4 show, the leakage rate of the designed system is much lower than that of the existing system, which can reach a minimum value of 10. 25%.

The experimental results show that compared with the existing power inspection robot automated control system, the designed power inspection robot automated control system greatly reduces the leakage rate, which fully demonstrates that the designed power inspection robot automated control system has better performance.

4. Conclusion

With the development of modern industrial technology, the technical level of industrial automation is getting higher and higher, and the inspection work of substation also tends to be automated, and the research of substation inspection robot adapts to this development trend. Nowadays, with the rapid development of mobile robot technology, the use of inspection robots in substations to fully replace manual or partially replace manual to complete the inspection work, must become the future development trend of automated substation site inspection. Substation inspection robot to assist or replace the staff of the substation equipment inspection work, not only so that the substation equipment condition detection accuracy has been greatly improved, but also to make the inspection of real-time and automation level is also greatly improved, and its motion control system is directly related to the substation inspection robot's work is stable or not.

The designed automated control system of power inspection robot greatly reduces the leakage rate, which can provide more effective guarantee for the safe and stable operation of the power system. However, the experimental data show that the leakage rate of the designed system still exists and is relatively high, so it is necessary to carry out further upgrading research on the designed system.

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