Application and Design of Inspection Robot System Based on Multi-parameter Hierarchical Inspection of UHV Substation

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Abstract. In this paper, a new substation inspection robot system is introduced, to meet the application requirements of multi-parameter full-station automatic hierarchical inspection of the insulation status of power equipment in UHV (Ultra-High Voltage) substation. The system is designed to control the inspection of substation robots, including identifying the number of meters on the cabinet, measuring partial discharge, measuring temperature and humidity and so on . The system is divided into two parts. One part runs in the robot body ,which is called the body control system , and it contains web server, robot ground control system and database. The other part runs on external industrial computer, which is called station control service system. The function of the body control system is more specific, mainly for controlling its own motor driver, in order to complete its own motion. The station control service system achieves important logic control, including configuring inspection plan, visual recognition, robot walking path planning, and writing inspection results into the database.

1 Introduction

UHV substation is an important part of the power transmission network. The equipments and environmental conditions in the substation directly affect the normal operation of the substation network[1]. Therefore, the substation equipment inspection is a basic work to effectively ensure the safe operation of substation equipment and the reliability of power supply. The traditional inspection method is manual inspection that operators regularly or irregularly, manually or hand-held terminals to inspect on-site equipment inspection. In addition, operators are required to conduct infrared temperature measurement of substation equipment once a month through a handheld infrared camera. However, this method generally has disadvantages such as high labor intensity, low work efficiency, and high management cost. Not only cannot achieve 24-hour inspection, but sometimes negligence exists in the manual inspection[2].

With the modernization and automation of UHV power transmission and transformation system, the electric inspection robot, which is gradually replacing manual inspection, has developed rapidly in recent years. in the face of challenges such as various system equipment, complex cross-linking relationship and increasing difficulty in observing component defects. So the substation equipment inspection system based on intelligent robot is put on the agenda and vigorously promoted. Substation robot inspection system is a complex system which integrates multi-sensor fusion technology, electromagnetic compatibility technology, navigation and positioning technology, behavior planning technology, robot vision, wireless transmission and communication. Labor intensity, low efficiency and high management cost are insufficient.

The inspection robot generally uses a wheel structure and it can walk freely on the ground[3]. There is a full set of system work software inside the robot. However, the system design is not strong enough that some problems exist. In the UHV substation, the inspection route is so long that low power consumption and high reliability of the robot is needed. But the robot body system software is too large, resulting in high CPU(Central Processing Unit) load, high power consumption or even system crash.

In this paper, a kind of improved inspection robot control system is introduced. The system has the following characteristics:

1) Movement and control are separated, the body control system is responsible for movement, and the station control service system is responsible for control[4].
2) Streamlining the body system. The ARM chips embedded in the robot ontology system can reduce power consumption effectively and prevent downtime.
3) The RGCS (Robot Ground Control System) is used to send commands to the robot, controlling the robot's motion and completing the inspection tasks.
4) Task status mechanism. Each inspection task will go through multiple states, and supports pause tasks and then starts a new task mode.

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The system is applied in a wheeled inspection robot which is runing in a UHV substation. The appearance is of the robot is shown in figure 1.

Fig. 1. Appearance of wheeled inspection robot

2 Substation Inspection Robot System

2.1 System structure

The system architecture is shown in the figure 2. The system is seperated into two parts. The station control service system which is installed in the external server contains web server, RGCS and Database. The Body Control System which is installed in the robot body contains robot body program, motor driver and other peripherals.

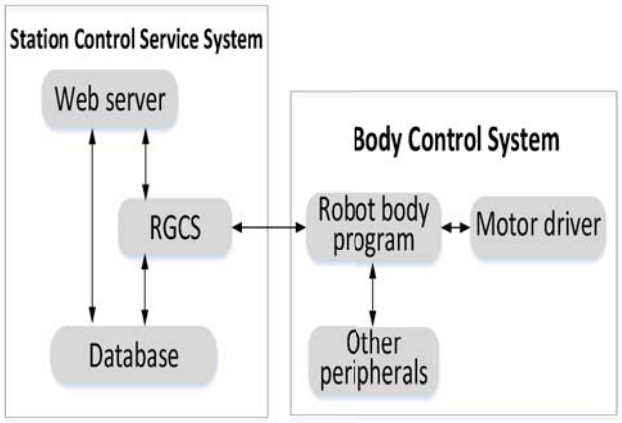

Fig. 2. Inspection robot system

2.2 Web server

Web server is a website service program that provides graphical interface operations. Its functions are as follows:

1) Users can complete the inspection plan through the program, and write the configuration of the inspection task to the database.

2) The web server reads the inspection result information from the database in real time and displays it on the interface[5].

3) Load balancing (session support is also provided, for example, a user's IP accesses machine A of the application. All subsequent requests will be made to machine A).

4) The web server also provides an operation interface for manually controlling the robot.

5) The web server can uniformly count and process all requests.

6) The web server can also forward to different application server addresses for different URLs.

2.3 RGCS

RGCS(Robot Ground Control System) is an open source meta operating system for robots. It provides the services that the operating system should have, including hardware abstraction, low-level device control, implementation of common functions, inter-process messaging, and package management. It also provides tools and library functions for obtaining, compiling, writing, and running code across computers.

RGCS is the core control module for the execution of inspection tasks. The functions implemented are as follows:

1) Continuous rotation training database to find the current inspection task to be performed.

2) According to the content of the inspection task, a series of control commands are generated and sent to the robot to move the robot to the target position. Then, the inspection operation of the position is implemented, such as taking pictures, visual recognition, reading the value of the sensor, etc.

3) Write the inspection results to the database.

4) Receive the manual control commands sent by the Web server, generate corresponding control commands and send them to the robot.

2.4 Database

The database is responsible for recording the power equipment, inspection route planning, inspection items and other related contents corresponding to the inspection task.

The functions of the database are as follows:

1) Realize data sharing: Data sharing includes that all users can access the data in the database at the same time, as well as that users can use the database through interfaces in various ways, and provide data sharing.

2) Reduce the redundancy of data: Compared with the file system, the database realizes data sharing, thereby avoiding users from creating application files. Reduce a lot of duplicate data, reduce data redundancy, and maintain data consistency[7].

3) Centralized control of data: In the file management mode, data is in a dispersed state, and different users or the same user have no relationship between their files in different processing. The database can be used for centralized control and management of data, and the

organization of various data and the relationship between data can be expressed through the data model.
4) Failure recovery: The database management system provides a set of methods that can detect and repair failures in time to prevent data from being destroyed. The database system can recover as soon as possible the faults that occur during the operation of the database system, which may be a physical or logical error. For example, data errors caused by misoperation of the system.
5) Centralized control of data: In the file management mode, data is in a dispersed state, and different users or the same user have no relationship between their files in different processing. The database can be used for centralized control and management of data, and the organization of various data and the relationship between data can be expressed through the data model[8].

2.5 Robot body program

The robot body program is responsible for receiving the control commands sent by RGCS, then sending the motion command to the motor driver, the robot can move to the target position by adjusting the wheel speed and steering and feed back the position information to the RGCS. At the same time, it can also accept and give feedback from the remote control, mobile terminal and other peripherals.

3 RGCS

3.1 System structure of RGCS

RGCS, playing the role of the robot's brain, is the core module of the robot motion control, and embodies the thought of the separation of motion and control. RGCS is built on a distributed process (node) framework, and these processes are encapsulated in packages and function packages that are easy to share and release. At the same time, it also supports a joint system similar to a code repository, which can also realize project collaboration and release.

The structure of the system is in the figure 3.

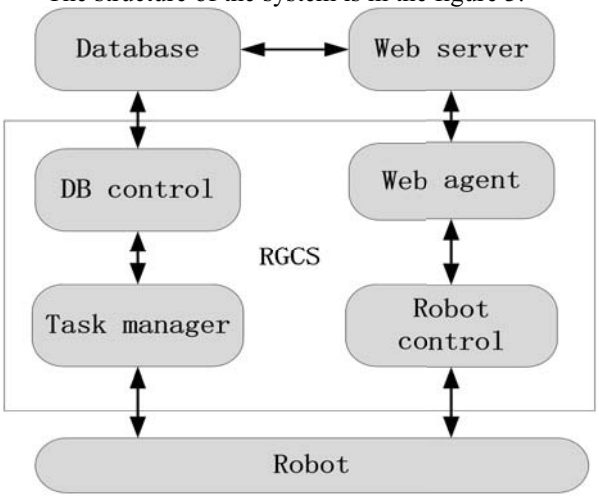

Fig. 3. Structure of RGCS

The system is divided into 4 modules. The web agent receives the manual control instructions sent by the web server and sends them to the robot control module after parsing[9]. The robot control module converts the instructions into the robot control command, then sends them to the robot to realize manual control. The DB(Data Base) control module provides all interfaces for database operations, it accepts the command information from the database and transmit it to taskmanager. The Task manager module is the task control module of the RGCS, which completes the automatic inspection of tasks. The following will focus on this module.

3.2 Task manager

3.2.1 Work flow of inspection tasks

The task manager sends the location information of the target points to the robot, including the coordinates of the target points, the position of the robot pan tilt, the camera magnification and the focal length value. These location information are saved when the robot does the inspection position modeling[10]. In the automatic inspection mode, the Task manager reads the location information of these target points from the database and sends them to the robot.

The robot controls the motor to move to the target position after receiving the location information, then adjusts the magnification and focal length of the camera, and finally feedback the sum of execution information to the Task manager.

After the task manager receives the sum of execution information, the robot has completed the main tasks, and the remaining tasks will be completed by the task manager. These tasks include controlling the camera in the robot body to take a photo, and then visually recognizing the photo to obtain the value of the instrument in the photo, or reading the value of the peripheral devices in the robot body, such as the temperature of the infrared camera, the temperature of the sensor, the value of the oxygen and carbon dioxide sensors, etc[11].

3.2.2 Inspection tasks state machine

Task manager implements a task state machine internally, which can be seperated into seven step state flow. The state diagram of the state machine is as follows:

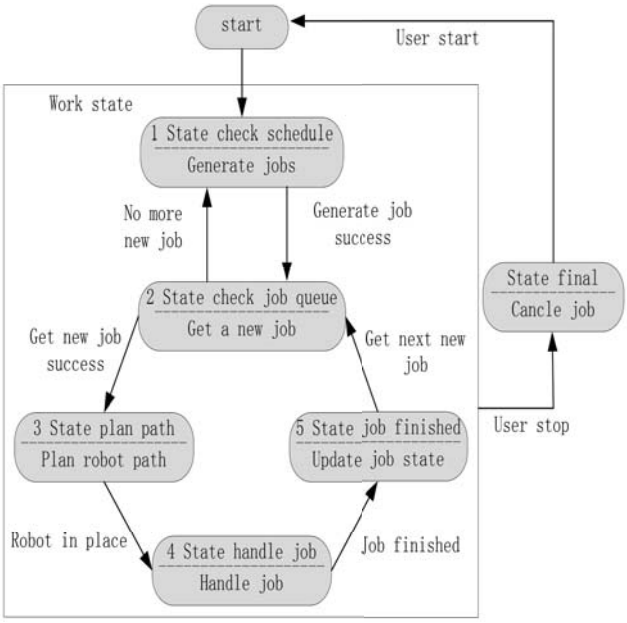

Fig. 4. Task state machine

State machine description:

1) start: The state machine starts and enters the automatic inspection mode.

2) state final: The state machine stops and enters the manual control mode.

3) state check schedule: Search the plan to be executed from the database, and then generate a series of inspection tasks according to the plan.

4) state check job queue: Take a task from the task queue to execute, if there is no task in the queue, enter state 1.

5) state plan path: Get new job success from state 2 ,then send location information to the robot, and then regularly check whether the robot is in place.

6) state handle job: After receiving the robot in-location information, start to do the inspection task, obtain the instrument and sensor values, and then go to state 5.

7) state job finished: Write the task results to the database and update the task status, and then go back to state 2.

The start and stop of the state machine can be set not only by internal program, but also by external controls. In this system, the web server module provides an interactive interface for the start and stop of the state machine. When the user needs to manually control the movement of the robot, the user must send an instruction to stop the automatic inspection to the RGCS. After receiving the instruction, the RGCS suspends/stops the currently executing task, and then makes the state machine jump out of the working state and enter the state final state while the user can manually control the robot[12].

After ending the control of the robot, the user needs to send an instruction to the RGCS to start the automatic inspection. The state machine transitions from the state final state to the working state after the RGCS receives the instruction, and continues to perform the suspended inspection task or starts a new inspection task.

4 Summary

This paper presents a system design scheme for a new type of substation inspection robot. This scheme can simplify the complexity of the robot body system, and hand over complex logic control parts to the station control service system, finally the heat dissipation and power consumption of the control system are reduced, and the system crash is avoided. This paper also puts forward the scheme of RGCS system to control the robot to do the inspection task, and uses the task state machine mechanism to accurately and effectively control the robot movement.

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