A Study of Substation Inspection Robot

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A. Abstract：

Substation inspection is extremely important for maintaining the reliable operation of a power grid. The rapid development of robot-related technologies has enabled robots to perform functions such as smart inspection, remote monitoring, infrared hot spot detection, abnormal alarm notification and access control management. This will greatly improve the efficiency of inspections.

B. Research Content

The major contents of this study include case studies of domestic and foreign substation inspection robots, site survey of substations, and the introduction of field selection. Wanhua secondary substation was later selected as a follow-up verification field. After surveying the state of the art technologies and the complexity of the terrains, preliminary robot specification and inspection process planning were specified as: 1) the outdoor mobile platform Husky UGV were utilized in the robot; 2) the positioning navigation was mainly based on VLP-16 3D LiDAR; 3) the dual vision image sensing module were selected for image inspection; 4) the microphone array design with audio purification capable of eliminating unwanted environmental noises was applied for audio recognition. The hardware architecture of robots is shown in Figure 1.

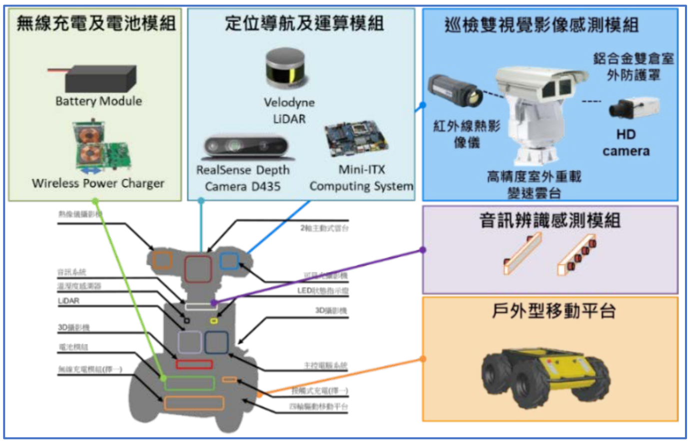

Figure 1　Hardware architecture diagram

To develop inspection robot, this study has developed related functions such as user interface (UI), system integration, tasks scheduling, reverse parking for wireless charging, localization, and navigation. The interactive communication between each software and algorithm has its own communication format. The software architecture is shown as Figure 2, which can be divided into the following three layers:

Upper layer: UI terminal, which can receive commands from users and display received data and messages.

Middle level: Windows PC, comparable to the human brain, receives and processes commands and schedules, and receives audio and video.

Lower layer: Linux PC, similar to human cerebellum and responsible for mobile navigation and 3D space positioning.

The communication between layers is completed through the function of high-performance message transmission library (Zero MQ) for network data exchange. For the efficiency of data transmission, in the software architecture, the UI side can bypass the brain (Windows PC) and directly access the dual image data of RGB Camera and Thermal Camera, or directly access and control the cerebellum (Linux PC) to confirm the robot's position and operation movement, which can reduce redundant data transmission. In addition, the image transmission is through the real-time streaming protocol (RTSP).

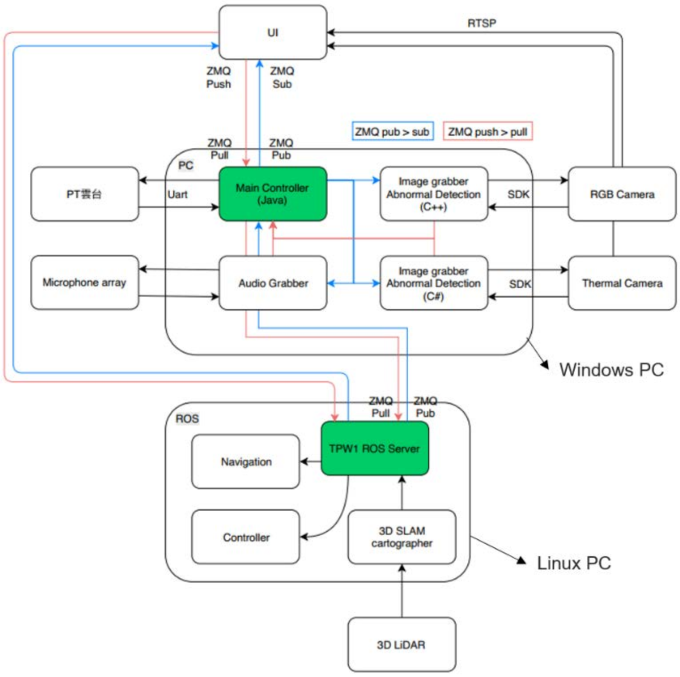

Figure 2 Software architecture diagram

The design of remote communication WiFi network architecture are as follows. Firstly, put a WiFi Router in the substation and use Media Bridge Mode to connect the robot’s internal WiFi Router. As long as it can connect to the WiFi Router, it can control and access the data of the robot. The control center is connected to the WiFi Router through an optical fiber network, and then the robot can be controlled and the data can be accessed, as shown in Figure 3.

Figure 3 WiFi network architecture diagram

The design of the 4G/5G communication network architecture is similar to the above WiFi network architecture, but the robot must be equipped with a 4G/5G router or original WiFi router, and the WiFi router in the substation needs to be changed to a 4G/5G. The original WiFi communication of Taipower’s intranet has been changed to the internet communication.

To meet the conditions of on-site maintenance and inspection, a total of 5 robot active inspection points (such as power fuses, gas circuit breakers, transformer oil level gauges, and two circuit breakers in sequence) are set for Wanhua Secondary Substation. Besides, some inspection positions and observation targets can be displayed, as shown in Figure 4- the red dots of the figure indicate the position of the robot. The green dotted line is the inspection route for robot, and the white gradient triangle is the robot's observation angle.

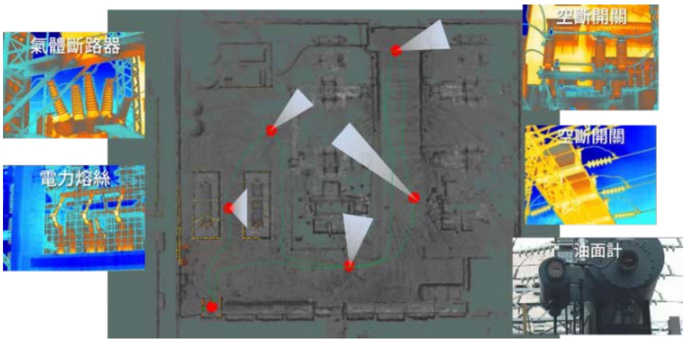

Figure 4　Inspection route and observation target of active inspection for robot

Passive inspection planning and setting include inspection plan, inspection time, inspection position and data collection type (visible light, thermal image and audio) and other functions. This study also develops a set of operation interfaces for passive inspection which allows remote users to observe the live inspection through a software screen and real-time remote control. This software has been installed in the control center of Taipower. It can be connected to the inspection robot through WiFi and Taipower's intranet. Finally, it has been verified that the remote passive inspection and functions can be used successfully, as shown in Figure 5.

Figure 5　Performing passive inspection in central control center of Taipower