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Design of Train-Ground Integration Condition Monitoring Terminal

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Abstract. The traditional train condition monitoring system and train control system is independent of each other; therefore, it has the problem of response lag and unstable. Once abnormal condition happened, it is easy to cause heavy casualties and economic damage. This paper introduces a design of train-ground integration's condition monitoring terminal. It can realize the communication between monitoring system and control system, achieving the automatic fail-safe handing, guarantee the safety and stability of the train operation.

Keywords: train-ground, integration, train control, two-out-of-three redundancy

1. Introduction

Urban rail transit system continuous to develop since created, and it has become a complex huge system. Once a serious accident happened to the system, it will cause heavy casualties and huge economic losses, and brings serious social problems. Hence, how to guarantee the safety of train operation has always been the focus on the research field of urban rail transit system [1, 2]. With the continuous development of computer technology, communication technology and sensor technology, train condition monitoring system has been paid more and more attention. Through the teal-time monitor of the axle box, gear box and other key parts' condition, the hidden dangers will be detected timely, and the accidents will be reduced [3].

The traditional train condition monitoring system and the train control system are independent of each other. Once the train condition monitoring system monitors abnormal state, the ground staff will use the Automatic Train Supervision (ATS) system to send a remote control command to Carborne Controller (CC) or Zone Controller (ZC), to realize the fail-safe processing. But in this case, it will bring two problems: (1) depends on the manual operation, and it will easily cause the response untimely and the risk is not controllable; (2) depends on monitoring terminal and monitoring central server, the remote communication between ATS system and CC or ZC. It has the risk of stability [4,5].

Train condition monitoring terminal is the most important part of the whole supervision system. The paper introduces a design of train-ground integration's condition monitoring terminal. On the one hand, it uses 4G network and monitoring central server for communication, therefore, the ground staff can master the real-time state of the remote vehicle and road condition. On the other hand, using the wired LAN and train carborne control system or CC system for communication, it realizes automatic fail-safe treatment, improving the ability of handling the accidents, ensuring a safe and reliable train operation.

2. The General Structure of the System

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The complete set of train monitoring system consists of three parts: the scene monitoring terminal, Automatic Train Control (ATC), the monitoring central server (as shown in figure 1). The scene monitoring terminal can be placed on the ground area, using for monitoring the invading, flooded, fire and other conditions. And it also can be placed on the train to realize the condition monitoring of axle box temperature, carriage temperature, speed, position, fire and other conditions. Through the 4G wireless network, the scene monitoring terminal sent the scene state data and the abnormal alarm data to the monitoring central server, and the monitoring central server provide the administrative access, status online query, warning notice, record query, report generation and other functions. Through the Ethernet and ATC system, monitoring terminal achieves the data communication, and through the Train Operator Display, the drive can view various real-time state information of the train. In the event of the abnormal situation happened, ZC or CC will perform the corresponding action to realize the fault emergency treatment, and ensure the safety of the train operation.

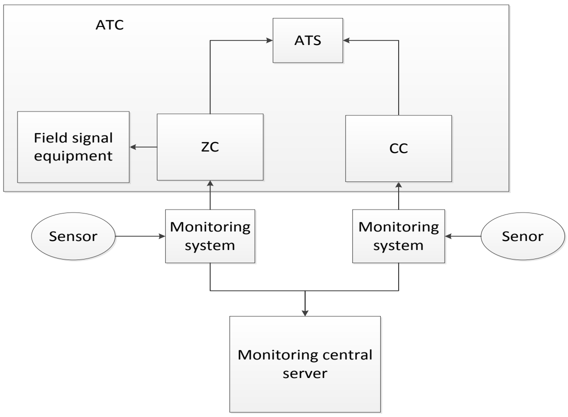

Fig. 1: Train monitoring system main structure.

3. Hardware Design of Monitoring Terminal

The system hardware part includes the following several modules: processor module, data storage module, power adapter module, sensor data acquisition module, communication control model, (as shown in figure 2). The processor module uses PowerPC processor to ensure the high performance of the system operation and control. Data storage module including RAM and Flash, and they respectively provide application space and data storage space. Sensor data acquisition module including physical interfaces of various sensors and protocol conversion chip to achieve communication of various types sensors (including the MVB bus and RS485 bus, etc.). Communication control module includes 4G communication module and Ethernet communication module. The power adapter module converts the external 110V AC power supply to all kinds of voltage required by the system.

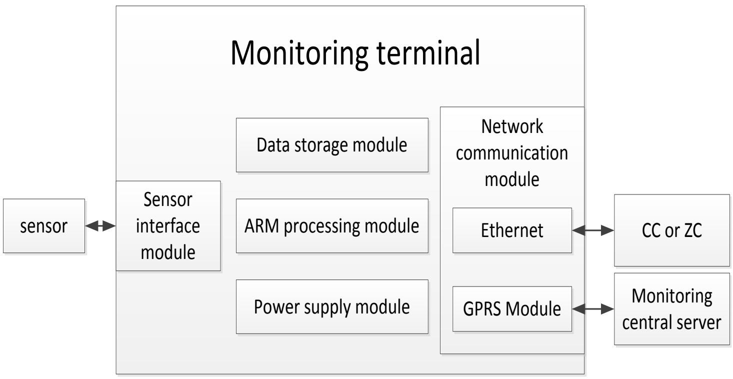

Fig. 2: Monitoring terminal hardware structure.

Since the train monitoring system needs to be combined with the train operation control system, so there is a strict requirement for the security of the system. Therefore, the system adopts two-out-of-three redundant structure to build (shown as figure 3), only when two or more than two modules failure at the same time (which happened probability of rare event), the system will put out the wrong result. The key technology is that the three CPU modules will respectively process the input sensor data independently, and then vote for synchronous processing results, only when the two or more than two results are the same, the result will be put out as the final result. The technology designed by independent TriSVB bus, the bus interface include the transceiver controller of high speed serial data bus, general CPU bus interface, synchronization state controller and hardware two-out-of-three voter, using FPGA to physical implementation. For sensor input module and network communication module, adopting the structure of double machine hot standby, once the inspection to the main system failure, it will automatically switch to the standby system, ensure the normal operation of the system.

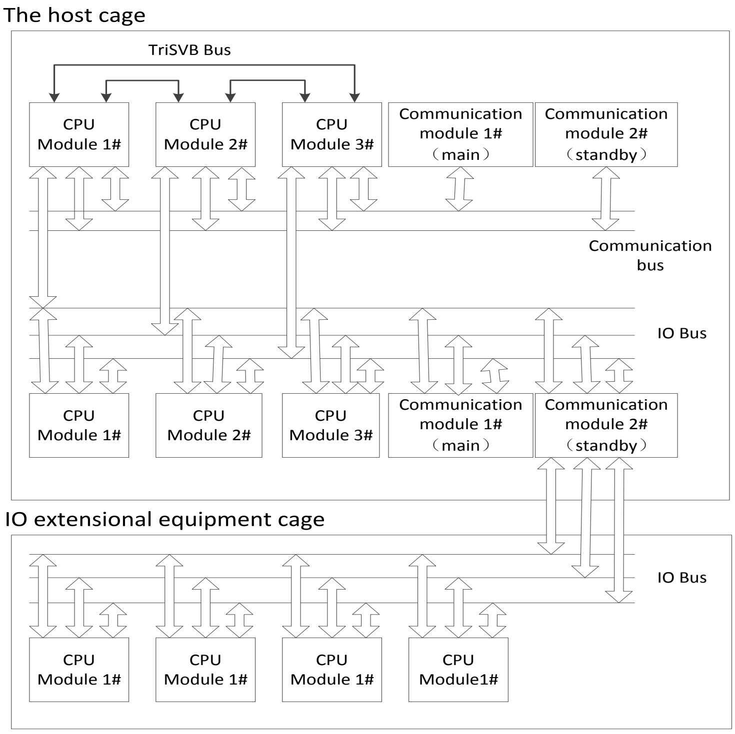

Fig. 3: Two-out-of-three redundancy structure.

4. Software Design of Monitoring Terminal

Software including three parts modules: data acquisition module, data processing module, network transmission module. The whole system structure and data flow as shown in figure 4.

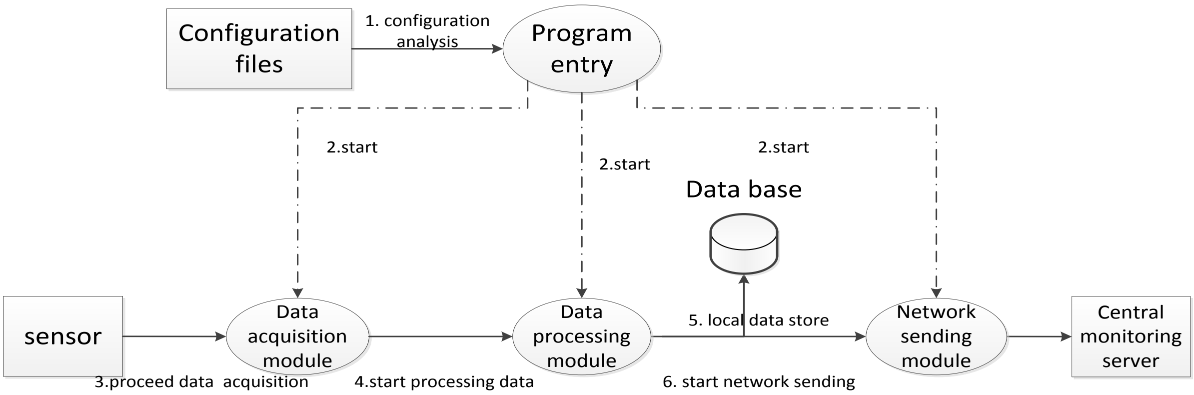

Fig. 4: Main monitoring software structure.

Data acquisition module is responsible for protocol analyzing the data communication with the sensors to get the required physical quantity. According to different types of sensor data, the data acquisition module includes periodic gathering tasks (such as axle box temperature, axial pressure, etc.), and trigger collection tasks (such as infrared invasion). The data acquisition module uses the event driven model to achieve the rapid response for the collection task, and reduce the occupation of system resources at the same time, (the specific processing as shown in figure 5).

Data processing module is responsible to collect the original data for a series of algorithm process and data analysis, and then get the final state data to upload. If the state data is abnormally, it will produce the corresponding alarm data, at the same time, according to the different alarm level, it will output the control signal to the different external object. Network transmission module processes the serializing and encrypting dispose to the state data and alarm data; finally, according to the internal communication protocol of application layer and TCP protocol, the network communication between central monitoring server and train control system has been achieved.

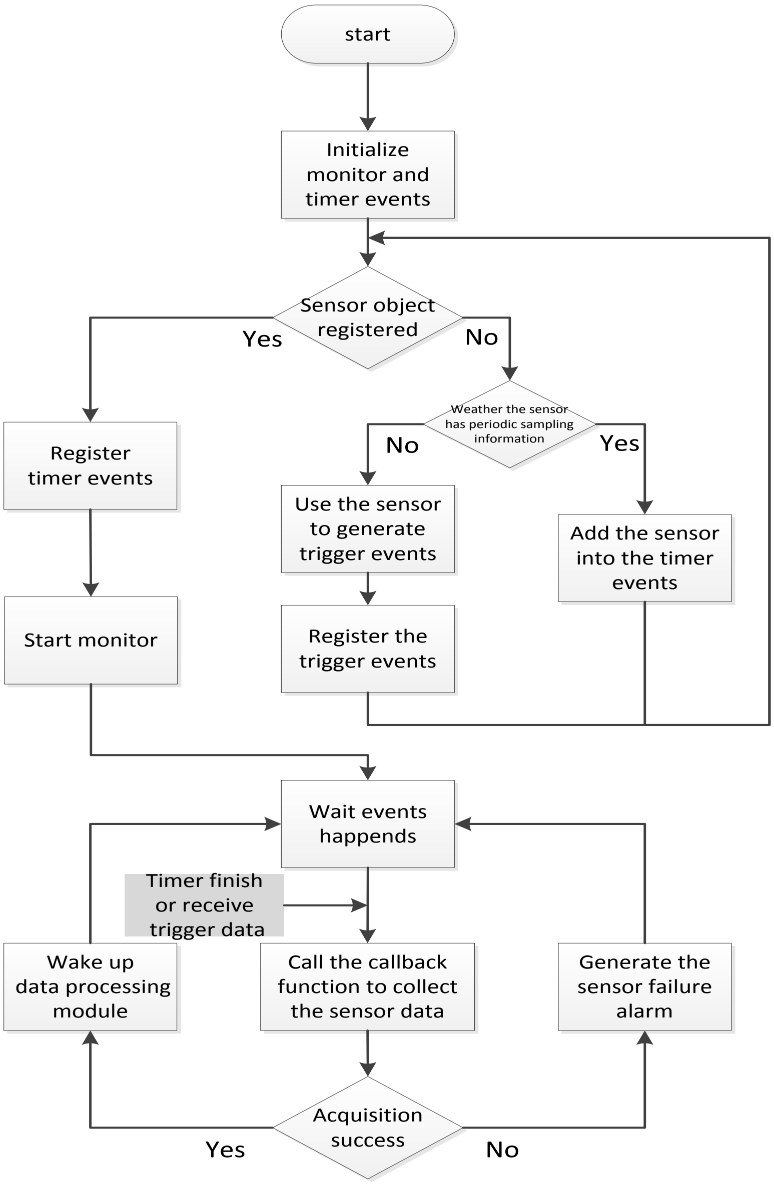

Fig. 5: Flow chart of data acquisition.

5. Fail-Safe Control Technology

On the one hand, the train monitoring system can communicate with CC or ZC for local data transfer, on the other hand, it can processes the data communication with the central monitoring server. Based on the two data communication modes, the system can achieve the following two kinds of fail-safe control mode: automatic control mode and manual control mode.

5.1. Automatic Control Mode

Through the combination of the monitoring terminal and ATC system, the system can achieve the fail-safe automatic control.

When carborne or wayside train monitoring system monitor a serious alarm data, for example, someone break into the forbidden area, fire alarm, the train monitoring system will sent the alarm data to CC or ZC. ZC can let the Movement Authority Limit (MAL) return to the area entrance; according to the different circumstances, CC will take speed limit, emergency stop, buckle train, skip-stop and other measures to ensure the safe operation of the train. And the above is a totally automatic control process achieved by the combination of train monitoring system and ATC system, need no staff to get involved, and it ensure the reliability and timeless of fail-safe emergency handing.

5.2. Manual Control Mode

Through the combination of monitoring terminal, monitoring central server and TOD system, it can achieve the fail-safe active control.

The ground staff can grasp real-time state data of the train, rail, station and other data by monitoring central server. And at the same time, the driver can also check the train state data by the TOD system. Once receiving the alarm data or pre-judging the risk, the ground staff will control the train and the area interlocking system through the ATS system, and the driver can achieve the train safety control manually through the CC system.

6. Summary

Through the combination with the trail control system, the design of train-ground integration’s condition monitoring terminal upon completion of the train and wayside condition monitoring function, but also can achieve a variety of fail-safe control. It fully guarantees the safety of train operation, and it has important practical application value.

7. Acknowledgements

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