Development and Application of Real-Time Online Monitoring System for Long Transportation of Large Power Transformer

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Abstract. A set of transportation process monitoring system for large power transformer transportation is developed, including transportation state intelligent acquisition terminal, monitoring system platform software and mobile app. The effectiveness of the system is verified in the actual transportation monitoring of converter transformer. It solves a series of problems existing in traditional methods, ensures the transportation safety of large electric power equipment and reduces the investment.

1. Introduction

Converter transformers need be transported from the factory to the converter station during the construction of HVDC project. There are some regulations on the transportation of transformer [1]. The traditional mode is to analyze the status data after the transformer is transported to the station [2,3]. This mode is unable to monitor and trace in real-time, so the abnormal condition during transportation can not be found and handled in time [4].

In order to monitor the real-time status of transformers during long transportation remotely, it is necessary to use reliable sensors to monitor the vehicle speed (ship speed), three-dimensional impact acceleration, tilt angle, inflation pressure, ambient temperature and humidity during transportation [5]. Meanwhile, GPS satellite positioning technology and GIS geographic information system technology shall be used to trace the transportation process of transformers, GPRS technology or satellite communication technology shall be used to transmit the data of transportation monitoring terminal remotely, intelligent computing technology shall be used to collect, calculate and analyze the transportation status [6, 7].

This paper designed and developed a monitoring system for converter transformers and applied the system to the transportation of actual converter transformers in HVDC project.

2. Framework of transportation monitoring system

Transformer transportation monitoring system includes intelligent monitoring terminal, monitoring system platform and mobile app. The intelligent monitoring terminal collects the transportation status of transformer through high-precision sensors, determines the position of transformer through GPS, and transmits information through GPRS wireless transmission technology. The monitoring system...
platform realizes the transportation monitoring management function of multi-access and multitask. Mobile app based on Android and IOS can improve the convenience and efficiency of transportation management.

The transportation monitoring system adopts three-layer frame structure design, as shown in Figure 1.

![Architecture diagram of the system](image)

**Figure 1.** Architecture diagram of the system.

The first layer is the central master station, which is configured with corresponding monitoring server according to management requirements, and installed with transportation monitoring system platform software, including communication service program and application service program.

The second layer is the mobile server which installs the mobile app server program. At the same time, the mobile app is installed on the mobile phone.

The third layer is intelligent monitoring terminal devices which collect various transportation status data. All the data is transmitted to the central master station server through GPRS/IOT wireless communication, and then processed by the application server and published by web. Thus the real-time remote monitoring of transformer transportation can be realized through web page or mobile terminal.

3. **R&D monitoring terminal**

3.1. **Sensor selection**

Sensors are used to obtain the impact acceleration, speed and position information during the transportation of transformer, collect the pressure data and environmental temperature and humidity data, and upload these data to the server on time.

1) Impact acceleration sensor: high speed triaxial impact acceleration sampling chip is used to realize online monitoring of triaxial impact acceleration in the whole process of transportation.

2) Position and speed sensor: the position information is obtained by the GPS module, and the speed data is processed by the position information. It is connected to the main control unit through UART, and the speed information is acquired once a second, and then sent to the server after processing.

3) Pressure sensor: collect and analyze pressure data through ADC function, convert pressure signal into electrical signal using MEMS technology, and upload it in real time through wireless communication network.
4) Temperature and humidity sensor: the temperature and humidity chip based on MEMS technology is adopted, and the digital interface is connected with the main control unit directly.

3.2. Intelligent monitoring terminal
Monitoring terminal uses Contex-M4, a low-power high-speed processor, as the main processor. GPRS communication and GPS positioning function are realized by GPRS module and GPS module. Three axis shock acceleration collection function is realized by electronic shock acceleration chip. Air pressure collection is realized by on-chip ADC and external pressure sensors. Principle diagram is depicted in Figure 2.

![Figure 2. Principle diagram of the monitoring system.](image)

3.3. Terminal and sensor installation
For monitoring purpose two type of sensors are used. The transport monitoring terminal is hardwired with the transformer body and installed on the top or side of the transformer. The pressure sensor is installed on the air pressure monitoring port on the transformer body. The specific installation diagram is shown in Figure 3.

![Figure 3. Installation of the terminal.](image)

4. Monitoring system platform
The monitoring system platform software adopts B/S architecture design, supports remote web access login, supports multi-user and multitask rights management.
4.1. Function diagram of the monitoring system

The monitoring system platform covers all aspects of transportation tasks, and makes statistical analysis of transportation historical data from six dimensions to provide decision support for future transportation plans, as shown in figure 4.

The monitoring system platform software adopts modular design, supports multitask and multi-user sub authority management, and is convenient for personnel with different roles to use it.

4.2. Function realization of monitoring system

The front page interface of the monitoring system platform can view all transport tasks and display the overall information of all transformers in transit in real time, as shown in figure 5. The task management page supports multitask planning, tracking and management, as shown in figure 6.

Figure 4. Function diagram of the system.

Figure 5. Homepage of the system.

Figure 6. Task management page of the system.

The task details page displays the latest status of the current transportation task, as shown in figure 7. The task track page displays the transportation track of the current task, as shown in figure 8.
The task information page displays the historical data and curves of the current transportation task, as shown in figure 9.

4.3. Data analysis
This system can carry on the statistical analysis to the accumulated historical transportation data.

1) View the progress of a single transportation task and analyze it in time series.
2) Analyze the status of each transportation task of the whole project, and view the completion proportion and proportion to be transported, etc.
3) Compare the transportation time of multiple transportation tasks in a single project, and analyze the transportation time trend under the same condition.
4) Compare the actual and planned status of transportation tasks, analyze the transportation speed and influencing factors.

4.4. Design of mobile app
The mobile app for transportation monitoring is a mobile display of the transformer transportation monitoring platform, which enables users to know the status more timely.
The app can display the current status of the transportation task and show the historical track and curve, as shown in figure 10. At the same time, the alarm information can be pushed, so that the relevant personnel can verify and confirm the abnormal conditions in the first time.

5. Engineering application
The transformer monitoring system has been applied in a ±800kV DC transmission project, as shown in Figure 11. IP65 protection level is adopted for monitoring terminal.

![Figure 11. Terminal Installation Diagram.](image)

The transportation lasts for more than half a year. The transportation path covers sea, highway and railway. More than 300,000 pieces of data are acquired. The trajectory and data are shown in Figure 12 and Figure 13.

![Figure 12. Trajectory diagram.](image)
Figure 13. Data curve of the converter transformer.

6. Conclusion
The monitoring system in this paper has been widely used in actual stations and achieved good results. The system realized the change from the arrival inspection to the whole process real-time online monitoring of large transformer transportation, which improved the transportation safety and management efficiency greatly.

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