Research on design of the real-time monitoring system for full hall steel tubular scaffolds

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Abstract. Full tubular scaffolds are widely used in substation engineering. However, full hall steel tubular scaffolds collapse can lead mass casualties without effective safety management. The real-time monitoring system for full hall steel tubular scaffolds can prevent collapse accidents. Aiming at the monitoring demand of full hall steel tubular scaffolds, research on design of real-time monitoring system is carried out. This paper mainly discusses system design principle, system function design and system formwork design. The function design part refines the different function permissions of users in different roles, and the framework design part analyzes the composition of the system and the way of data transmission.

1. Introduction
In recent years, to meet the demand of urban power supply, more and more indoor substations are built. In order to satisfy the needs of functional requirements, the height and structure of indoor substations are often more complex. Full hall steel tubular scaffolds are composed of steel tubes, fasteners and other detachable members [1]. Due to simple structure, strong universality and low cost, full hall steel tubular scaffolds are widely used in substation engineering. The height of the main transformer room and GIS room often exceeds 8m, and full hall steel tubular scaffolds are used for formwork support during construction.

However, full hall steel tubular scaffolds collapse is one of the sources of danger that can easily lead to mass casualties in construction. If construction safety risks of scaffolds are not identified and controlled, collapse accidents will be very likely to occur, which cause heavy personal casualties and property losses [2]. Therefore, it is necessary to monitor scaffolds during substation construction.

Traditionally, full hall steel tubular scaffolds can be monitored manually by total station. By this way, settlement and horizontal displacement excluding inclination angle and axial force are able to be measured. Compared with traditional monitoring, real-time online monitoring has the following advantages:

- Low risk: Monitor structure information by sensors without personnel present;
- Low cost: One-time investment for long-term monitoring;
- High efficiency: When scaffolds exist abnormality, the monitoring system can deliver warning information in the form of text messages or e-mail;
- Excellent service: Continuous huge amounts of data can be measured; even in extreme weather conditions, monitoring data at any time can be effectively obtained.
Based on the science and technology innovation project of East China Power Transmission and Transformation Engineering Company of State Grid, this paper designs a real-time on-line monitoring system for full hall steel tubular scaffolds in substation engineering to realize the visualization and intellectualization of monitoring process.

2. System design principles
The basic design principle of the system is that the system can monitor and manage full hall steel tubular scaffolds reasonably and effectively. The development of the whole system is carried out under the condition of ensuring the orderly connection and coordination of the relevant systems in each stage. Based on the obtained test data, structural security information should be provided; Based on the systematic structural risk analysis and structural response, the system can predict the dangerous state of the structure and carry out the corresponding active structural safety control. What's more, it provides safety guidance and monitoring reference data for construction of formwork engineering. According to the specific situation of this project, the following principles for designing the system should be strictly followed:

- Economy of the system: Collected data can ensure the effectiveness of the full hall steel tubular scaffolds monitoring, while taking into account the durability and cost of the instrument;
- System reliability: The established system should have high reliability. Since the real-time system runs outdoors, the reliability of the system should be guaranteed. Otherwise, the advanced instruments can't play their roles under the premise of system damage;
- Applicability of the system: The system can really be used to ensure the safety of full hall steel tubular scaffolds;
- Effectiveness of the system: According to the structure characteristics of full hall steel tubular scaffolds and safety assessment requirement, monitoring factors and monitoring scheme are designed;
- Operable and easy to maintain: The system should be easy to manage and operate, and requirements on the operational ability of technical personnel are not high;
- The system has good openness and compatibility: Under the premise of meeting the functional requirements, the rapid development of modern technology should be fully considered in order to upgrade the system. At the same time, it can connect with other construction monitoring systems and realize information sharing. Reserve hardware and software interfaces for system extensions;
- The system has the function of remote firmware upgrade: The system can be improved through the remote firmware according to the self-test and the requirements of the system, and the system has various types of communication protocols and interfaces, which can be used to upgrade the equipment;
- Optimal cost control: One principle of the monitoring system is to use the optimal layout control method to save cost, manpower and material resources for later maintenance, and maximize the effect of monitoring.

In short, the system adheres to the principle of "technical feasibility, economic rationality" and provides data and technical support for construction of formwork engineering.

3. System function design
The monitoring system has the following functions:
- Automatic monitoring: Various types of data such as settlement, axial force and inclination Angle can be monitored in real time. The alarm threshold can be set according to design. The system mainly monitors settlement, axial force, inclination Angle at key locations of full hall steel tubular scaffolds. When the monitoring data exceed the threshold, the system will warn timely, and remind on-site engineers to adopt necessary measures to ensure construction safety [3].
- On-site alarm: In order to give feedback timely to the occurrence of early warning information, an acousto-optic alarm is arranged on site. When the monitoring value exceeds the threshold value, it will automatically give an alarm by alarm sound or SMS.
Data display: Real-time data is recorded in the whole construction process. Data change trend is displayed dynamically by means of graphs, and historical records can be traced. The system collects, stores and analyzes the monitoring data, so as to guide the construction and improve safety reliability of full hall steel tubular scaffolds. Data analysis can be displayed by means of graphs, and historical data and historical alarm information can also be inquired.

According to the monitoring sub-items modular classification, the system unify data processing format, data transmission protocol and framework system to achieve replicable operation for Large-scale promotion and application.

Integration of collection, analysis and supervision: The system runs automatically and continuously during the construction phase. Data collection and analysis are carried out simultaneously, and real-time monitoring data are transmitted to the back-end server. The structural defect is identified by analyzing a large amount of monitoring data. To ensure scaffolds safety, potential threats to structural safety should be assessed.

3D visual display: The system reserves the import interface of 3D model files, so that the model files generated by 3D modeling software such as Revit, AutoCAD, 3DS MAX and ANSYS can be imported into the system without error. The monitoring nodes in realistic scaffolds correspond to the monitoring nodes in the virtual 3D model. Users can observe change trend of monitoring data directly through the 3D display model, and the dynamic display of monitoring data is realized by assigning different colours to different ranges of data values.

Users’ permission: Different management permissions are configured for different managers to authenticate the logon users of the system. The user's permissions are divided into different levels, including super admin and ordinary user. The super administrator has full permissions, including managing all project, setting up new projects and configuring various parameters, Ordinary users only have access to view a specific project.

As shown in Figure 1, according to the above design functions, the main function modules of the system are designed in detail, including GIS Home Page, User, Alarm, 3D Display, Alarm Data Analysis, Journal, Configuration and Report. And sub-function modules are also designed in detail.

![Figure 1 System function module design diagram](image-url)
4. System framework design
The hardware of this system includes sensors, data acquisition nodes, a data acquisition device, a server and so on. Data collected by displacement sensors, axial force sensors, inclination angle sensors are transmitted to data acquisition nodes via RS485 interface. The data acquisition nodes transmit the collected data to the data acquisition device through wireless zigbee network. The data acquisition device has the functions of data viewing, storage and alarm [4]. Then the data acquisition device can transmit the data to the server through the 4G network. Back-end engineers and managers can monitor scaffolds on the system in real time. The figure 1 shows the system framework.

5. Conclusion
This paper mainly discusses the design of the real-time monitoring system of the full hall steel tubular scaffolds, which mainly includes the design principles, function design, and framework design. The function design part refines the different function permissions of users in different roles, and the framework design part analyzes the composition of the system and the way of data transmission.

Acknowledgments
This paper was supported by the science and technology innovation project of East China Power Transmission and Transformation Engineering Company of State Grid.

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