Application of smart substation site management system based on 3D digitization

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Abstract. In order to standardize the construction of smart construction site of substation, meet the requirements of observable, measurable and controllable whole process of project technology, safety, quality, progress and procurement, and realize the goal of lean management and control, this paper expounds the concept of smart construction site from four aspects: Framework Construction of smart construction site, platform and module construction of smart construction site, mechanism construction and pilot application. This paper puts forward an overall scheme of smart substation construction site based on 5g technology, which combines big data, artificial intelligence, state perception and video recognition technology to solve the multi-dimensional management requirements of safety, quality and progress during construction. The intelligent site visualization platform is established and integrated with 3D model to realize 3D visualization display of site information.

1. Introduction
For high-quality development of power grid construction, based on the general idea of ‘intelligent infrastructure management and intelligent construction site’, this paper builds a framework model of intelligent construction site, uses one platform and six modules to realize digitization, intelligence and online project management, and improves intelligent achievements from mechanism, so as to save project management cost and improve management efficiency and management ability. An overall scheme of intelligent construction site based on 5G technology is proposed, which combines big data, artificial intelligence, state perception and video recognition technology to solve the multi-dimensional management requirements of safety, quality and progress during the construction period. The intelligent site visualization platform is established and integrated with 3D model to realize 3D visualization display of site information, as in [1-2].

2. Construction of smart construction site framework for substation
Substation construction site management usually involves process, materials and resources, space layout, quality supervision, progress control and cost management etc. the real-time management of smart construction follows three basic characteristics of intelligent construction: integration, wisdom and sustainability, it focus on the management practice activities of project construction and operation, and also on the project construction and operation. The visualization, efficiency, real-time and
accuracy of management activities at all levels in the whole process are emphasized and reflected, such as those shown in Figure 1 and Figure 2.

Figure 1. Intelligent construction site management system based on 3D model.

Figure 2. Framework of intelligent construction site management system based on 3D model.

Figure 3. Basic framework of substation intelligent construction site.
In order to realize real-time, dynamic, accurate, visual and sustainable site intelligent management, the rapid development and maturity of Internet of things, cloud computing and three-dimensional model technology under the background of big data era provide the possibility for future project practice, as in [3-4]. On this basis, based on digital design and three-dimensional technology, it introduces remote monitoring, virtual reality and other means in an all-round way, innovates the management concept and management mode. According to the importance of infrastructure projects, project area, safety and quality requirements, communication channel conditions and other factors, the ‘smart site’ is configured in layers and levels, and the ‘platform’ is proposed for site management. The basic framework is shown in Figure 3.

3. Substation intelligent site platform and module construction

The ‘Platform’ is a set of systematic products combining software and hardware. Through the closed-loop process of monitoring and data collection of hardware equipment, statistics and analysis of platform, an interconnected collaborative and safety monitoring system based on construction process management is established. Through mining and analyzing the collected data, it provides prediction and plan, and realizes the visualization and intelligent management of the construction site.

‘Module’ is a unit that can realize specific functions by relying on information system and hardware equipment according to the voltage level of construction site and factors of ‘human, machine, material and environment, as in [5]. The more ‘modules’ are, the stronger the integration function of intelligent construction site is, and the more conducive to promoting ‘intelligent infrastructure management and intelligent construction site’.

The ‘Platform’ includes: (1) integrated management module; (2) safety management module; (3) quality management module; (4) schedule management module; (5) technology management module; (6) procurement management module.

4. Construction of smart site mechanism for substation

Establish a linkage mechanism and create a smart site promotion group composed of functional departments and project divisions, with infrastructure as the leading department and safety supervision, human resources, Party building, office, logistics center, information center and project divisions as supervision units to regularly study and coordinate project supervision.

5. Wireless transmission

5G wireless transmission is used in the construction site, sufficient bandwidth ensures the smooth image preview, no wiring, no need to worry about the damage of traditional site monitoring wire rod, and saves a lot of power and signal lines. At the same time, the equipment can be used repeatedly. For example, after the construction site is completed, it can be removed and replaced by other construction sites for continuous use without any additional cost.

6. Solution for 3D construction and substation installation

The information provided by 3D platform includes model shape, model attribute, construction progress simulation, construction hoisting simulation, construction transportation simulation, equipment test simulation and other information provided by design source. The information provided by the perception layer includes UAV monitoring, video probe monitoring, sensor monitoring, CSS positioning monitoring, RFID chip identification, access control identification and other real monitoring and sensor information, as in [6-8].

Through the network transmission to the electric power Internet of things for integration, the application effect of learning from each other and complementing each other can be achieved, and the construction goal of "smart site" can be achieved.
6.1. 3D simulation of construction process

The schedule of substation construction is usually represented by 2D bar chart. Because the construction and installation is a highly dynamic process, this method can not clearly describe the construction progress and various complex relationships, and it is difficult to accurately express the change process of engineering construction.

The construction progress bar chart based on 3D model is established. With the dynamic visualization effect of the three-dimensional model, a new type of progress bar display mode is formed in the form of movie playing and tentative at any time, which directly reflects the intermediate process of the station construction. Meanwhile, it is closely combined with the actual construction progress, and the real-time work information and personnel information of the day are synchronously displayed in the current three-dimensional progress simulation.

Through the intuitive display of the progress of the 3D model crossing, it is convenient for the project management personnel to reasonably formulate the construction plan, accurately grasp the construction process, optimize the use of construction resources and carry out the construction layout scientifically.

6.2. Regular comparison between real scene monitoring and 3D Model

The UAV is used to carry out aerial panoramic monitoring regularly. Combined with the video probe of key construction parts, the three-dimensional model is fused and compared to visually control the construction quality deviation and progress deviation, as is shown in Figure 4.

![Figure 4. Schematic diagram of regular 3D real scene comparison.](image)

Using high-precision UAV and 3D laser scanning, we can obtain every corner of the construction site with high efficiency, realize the global visualization of 3D real scene, and make the hidden project traceable. Regular collection of 3D real scene model, in the 3D Witness Project, the use of 3D model data for visual comparison of scheme differences, through data analysis software for both compliance deviation analysis, combined with real-time construction information input, and the planned construction progress in the form of data, charts and other forms of visual dynamic comparative analysis. Control the construction quality deviation and progress deviation, finally realize the dynamic and accurate control and intelligent management of the project, reduce the risk of construction delay, and improve the construction efficiency.

6.3. Visual monitoring and early warning during construction

Sensors and video probes are used to monitor the equipment, instruments and personnel in high-risk construction links. Combined with the three-dimensional construction organization scheme, real-time monitoring and early warning are carried out for the safety activity areas of key people and objects.

6.3.1. CSS positioning monitoring technology.

(1) Personnel orientation

With the help of real-time positioning technology of linear frequency modulation and spread spectrum (CSS), the wireless positioning base station is arranged in the civil engineering lofting stage of the
substation construction, and the wireless positioning function in the intelligent safety helmet is used to collect the positions of the construction personnel in real time. The personnel entering the construction site can be displayed and managed according to different levels and types, and the current position of the personnel can be queried and displayed on the physical plan in real time.

(2) Virtual fence
In the station area, the scope of safety activities during operation is marked. When the staff carry out construction work, the system can automatically judge whether the operation area is a safe area or a dangerous area, and supports the realization of early warning of illegal access to key areas. At the same time, it is linked with the video in the substation. When the staff are in the non-safe area, the monitoring equipment is determined according to the positioning area, and the video clips in this time period are automatically intercepted and saved in the server.

(3) Moving track tracing
It realizes the dynamic simulation and track recording of personnel position information on the 3D digital construction site, and saves the information such as the travel route of the staff in the substation in the database, so as to review the working route through dynamic mode in the future, so as to realize the effective supervision of the substation staff, as is shown in Figure 5.

![Figure 6. Real time monitoring schematic diagram of hoisting safety area.](image)

6.3.2. Real time monitoring in substation engineering. Taking the real-time monitoring and early warning in the hoisting process of the main transformer conservator in the substation as an example, as shown in the figure, the construction area is divided into the safety area and the defense area, and the
detector devices are distributed in all corners of the room, the key parts of the crane and all the construction personnel.

Person A, B and C are registered construction personnel in this process, and they can move normally in the defense area; Person D and E are not reported. When these two people enter the defense area, the system will automatically issue a warning and record it in the software platform, as is shown in Figure 6.

6.4. Sensor monitoring and model linkage

The sensors used in construction mainly use sensing equipment to collect data and image technology system from the construction site, such as component temperature, deformation, stress, equipment operation and on-site construction status, which reflect the useful information of various construction production factors and their states. At present, there are temperature sensors, displacement sensors, strain sensors, optical (wave) sensors, optical fiber and visual sensors.

In this project, the real-time linkage between sensor information of sensing layer and 3D model is proposed to realize the visual early warning of major construction risk points such as beam column deformation, foundation pit excavation, slope support and so on.

During the construction, four sensors are arranged on the four steel structure beams, and various technical data required by the construction site will be continuously collected during the hoisting construction. After A/D conversion, these data are connected to the digital platform in real time and combined with the three-dimensional model. On the front-end display interface, the location of the sensors is displayed in a visual form, and the real-time monitoring information and historical monitoring information of each sensor are displayed in the data table at the lower side, and the stress bearing degree of the current facilities is represented by a chart containing critical line and limit line.

Using sensors to collect and transmit the data needed for construction accurately and timely, so as to provide basic data for project decision-making and control, so as to facilitate the efficient construction control and management, and realize the basis of automatic information collection and input.

6.5. 3D simulation preview of complex working conditions

In the three-dimensional visualization environment, the construction scheme of complex installation conditions and important risk points is previewed in advance, and the construction progress, resources and quality of the whole project are uniformly managed and controlled, so as to achieve the purpose of reasonably optimizing the allocation of various resources and construction sites required, shortening the construction period and reducing the cost, and finally realizing the fine construction management and control in the process of project construction.

6.5.1. 3D simulation of transportation and hoisting. The simulation of equipment transportation and hoisting scheme in visual environment is carried out to verify the rationality of the design, and the construction organization plan is made in advance.

6.5.2. Application of MR technology in construction and installation.

(1) MR hybrid reality technology

Hybrid reality technology (MR) is the further development of virtual reality technology (VR). By introducing real scene information into virtual environment, MR builds an interactive feedback information loop among virtual world, real world and users to enhance the reality of user experience.

Hybrid reality is a combination of technologies that not only provides new viewing methods, but also provides new input methods, and all methods combine with each other to promote innovation. The combination of various bionic input and output makes the immersive wearable device break through the limitation of entertainment and enter into the actual production and life. Through customized development, hybrid reality applications can directly affect the workflow and help
enterprises and employees improve their work efficiency and innovation ability, as is shown in Figure 7.

Figure 7. Multi person real time design interaction in hybrid reality.

Figure 8. MR hybrid reality hoisting preview.

(2) Application of MR technology in complex working condition rehearsal
Visual preview of complex working conditions, combined with MR hybrid reality technology, aiming at the key and difficult points in the construction organization, the virtual construction simulation in the field environment is carried out. As shown in Figure 8 is a hoisting simulation picture of the second floor structural beam of the building. MR technology is applied to provide real-time interaction
between the digital world and the real world. In MR system, bionic operation access, event trigger design, information expression presentation etc.

The actual operation process is to select the construction process (e.g. hoisting of the second floor structural beam) → select automatic/manual operation → check crane information and lifting object information → carry out equipment operation (forward, backward, lifting, lowering, left rotation and right rotation). At the same time, MR hoisting simulation operation can also be compared with animation display of 3D hoisting design simulation, so as to restore the whole construction process as real as possible, so as to achieve the purpose of visual quality management, as is shown in Figure 8.

7. Conclusions
The establishment of substation intelligent construction site is an effective way to solve the problems of safe construction, civilized construction, intelligent construction and harmonious construction in the new era. This paper puts forward the concept of multi-dimensional design throughout the whole process of infrastructure construction under the premise of deep integration of modern engineering based on three-dimensional technology and 5G cloud technology, establishing hierarchical configuration of ‘smart site’, and realizing ‘platform + module’ of site management. In a word, making full use of artificial intelligence and virtual reality technology to further realize the ‘excavatable’ and ‘interactive’ functions of intelligent construction site will comprehensively improve the accuracy of each link of project management, reduce the risk of each link, improve the efficiency of design, construction, supervision, completion, settlement and other process nodes, reduce the total construction cost and construction risk, and popularize the independent operation of intelligent construction site Large, will be quickly realized in the next pilot and exploration. With the development of 5G technology, combined with big data, artificial intelligence, state perception, video recognition technology, the intelligent site visualization platform is established, and integrated with 3D model to realize 3D visualization display of site information. It can solve the current construction schedule and safety requirements.

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