Research on Visual Excavation Technology for Power Grounding Network Based on BIM and AR

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***Abstract*—The power grounding grid is the foundation for ensuring the safe and reliable operation of the power system, as well as the safety of equipment and personnel. Excavation is the core technical means for evaluating, repairing, and renovating the status of the power grounding grid. A large number of standards specify the excavation time and sampling requirements for the power grounding grid, but there are no specific requirements for the excavation process. Due to the characteristics of concealed engineering in the power grounding network, there are shortcomings such as blindness, large workload, and impact on system reliability in the excavation process of maintenance and renovation. Therefore, this article proposes a visual excavation technology for power grounding network based on BIM and AR. Through practical application in on-site excavation inspection of grounding network in a 110kV substation, it is shown that this technology can significantly improve the accuracy, efficiency, and digitalization level of power grounding network excavation.**

Keywords-visual excavation technology; power drounding network; BIM; AR

I. Introduction

The grounding grid of power plants, substations, converter stations, wind power system booster stations, energy storage stations, etc., referred to as the power grounding grid, is the foundation to ensure the safe and reliable operation of the power system in the energy Internet, and also the key and infrastructure to ensure the safety of equipment and personnel [1-3]. Excavation is the core technical means for evaluating, repairing, and renovating the status of the power grounding grid [1-6]. A large number of standards specify the excavation time and sampling requirements for the power grounding grid [7], but there are no specific requirements for the excavation process. Previous research on power grounding grids mainly focused on state assessment, fault diagnosis, corrosion analysis, parameter testing, etc., without any research on excavation of power grounding grids. Due to the characteristics of concealed engineering in the power grounding network, there are shortcomings such as blindness, large workload, and impact on system reliability in the excavation process of maintenance and renovation. Especially if there are missing ground grid design drawings or inconsistencies between the design and construction burial, problems such as inability to excavate or inaccurate excavation often occur.

With the digital transformation and upgrading of the power grid, the integration of BIM (Building Information Modeling) models and digital twin technology in substations has achieved synchronous construction of digital twin stations and physical stations, creating conditions for the full lifecycle control of substation design, construction, operation and expansion [8]. Augmented reality technology can truly implement the application of digital twin stations and promote the digitalization and informatization process of power infrastructure projects. AR (Augmented Reality) technology not only presents real-world information, but also displays virtual information simultaneously [9]. The two types of information complement and overlap with each other, and are currently applied in power training, auxiliary substation operation and management. The BIM model integrates various information of construction projects and has great advantages as a virtual information source for AR application on construction sites. At the same time, it continues the continuous use of BIM information throughout the entire lifecycle. Currently, the combination of BIM and AR has been applied in building construction site management and organizational coordination, but there is no application in the field of power grounding grid.

This article proposes a visual excavation technology for power grounding networks based on BIM and AR, introduces the technical principles and practical applications, realizes visual positioning of power grounding network excavation, and can significantly improve the accuracy, efficiency, and digitalization level of power grounding network excavation.

II. BIM Modeling of Power Grounding Network

A. Modeling Tools and Principles

This article uses the mainstream Revit series software of the year to establish a BIM model for the power grounding grid. In order to ensure that the BIM model of the power grounding grid meets the usage and accuracy requirements at all stages of the excavation lifecycle, the modeling is based on the following rules:

1. General principles for modeling, based on the requirements of the power industry, including the determination of modeling standards, file naming methods, etc.

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2. Naming rules for components, including naming conventions for various professional models involved in power grounding grids, coding methods for various professional components, etc.

3. The parameter setting rules for components, and the specification for setting the parameter categories and names of grounding conductor components in power grounding grids.

4. The spatial relationship rules of components determine the spatial relationships and connection requirements of different professional component models such as the above ground building and underground grounding network of the power grounding network.

B. Main Parameters of Modeling

This article selects a 110kV substation of Shanghai Electric Power Company as the actual research object on site. Obtain CAD drawings and design materials for the civil engineering part of the 2D design of the substation, and extract information related to BIM modeling of the substation grounding network as follows:

1. Grounding grid grounding body size: The horizontal grounding body adopts 120mm^2 copper stranded wire, and the vertical grounding body adopts a 14.2mm diameter copper clad steel grounding rod. The indoor grounding main line, equipment leads, and GIS room use 40 * 6mm hot-dip galvanized flat steel, and the lightning protection strip uses a 12mm diameter galvanized round steel. Therefore, the BIM model of the substation grounding grid uses rectangular columns and cylinders from the Revit family library.

2. Grounding grid size and burial depth: The total area of the station grounding network is about 1412.49 square meters. The conventional horizontal grounding body is buried at a depth of -0.8m underground, and the main entrance and exit are buried at a depth of -1.0m. The top elevation of the vertical grounding rod is -0.6m underground.

3. Specific layout of grounding grid: The specific layout of grounding grid is detailed in the 2D design CAD drawings, and the specific layout diagram of grounding grid is shown in Figure 1.

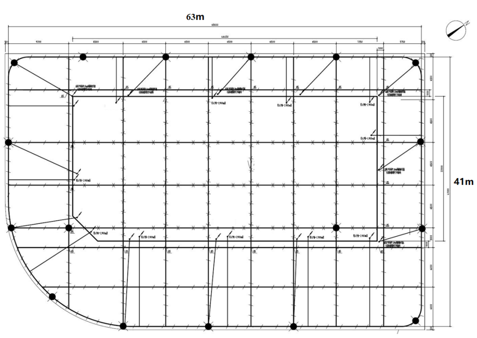

Figure 1. Specific layout diagram of grounding network for a certain 110kV substation

C. Results of Modeling

Based on the CAD drawings and design data of the civil engineering part of the 2D design of the substation, a BIM modeling was conducted for a 110kV Qingbai substation of Shanghai Electric Power Company. The above ground buildings of the substation were briefly modeled, and the grounding network was modeled in detail according to the design drawings. The modeling result is shown in Figure 2, forming one. rvt file.

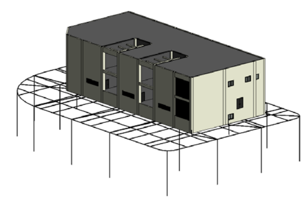

Figure 2. BIM modeling results of grounding network in a 110kV substation

III. Modeling of Substation Grounding Network based on BIM and AR

A. Modeling Methods and Steps

The design of the BIM model for substation grounding network must add corresponding information and go through some steps to create several forms of virtual scene models, which can serve as information sources for the relevant applications based on AR technology during the excavation stage of the grounding network. The specific modeling steps are as follows:

1. Using the BIM core modeling software Revit series to establish design BIM models, including building models, structural models, etc.

2. Make appropriate modifications and adjustments to the design model, create visual models, architectural analysis models, and comprehensive coordination models. The visualization model includes indoor and outdoor renderings, scene roaming, and corresponding display videos and other visualization results; Building analysis models include energy consumption analysis models, cost analysis calculation models, etc; The comprehensive coordination model includes a comprehensive model of underground pipelines for grounding networks, a collision inspection model, and so on.

3. Add construction organization design related information that can meet the requirements of construction tasks in the design model, such as excavation construction technology, excavation construction site layout, etc., and create excavation construction BIM models, including building, structural, and other models.

4. Using the various models mentioned above, combined with the application requirements of excavation construction in the later stage, the models are split and stored in corresponding sub model libraries according to different forms of model content.

5. The BIM model needs to go through certain processing before it can be called by AR applications. The specific processing process is to exchange information between different software through an object based, publicly available

data model format IFC (Industry Foundation Classes). The model in Revit software is saved in FBX format, and then this format file is imported into 3ds Max software for deep and detailed rendering processing. The file is exported as a WRL format file, which can be used as the virtual scene model of AR.

B. *Results of Modeling*

For the complex underground substation grounding network, construction and operation personnel conducted a 1:1 3D modeling based on the construction design drawings, stored the relevant model data and images in the information database, and stored this information in the AR equipment. When the display of the substation grounding grid function is enabled, the 3D image will be displayed on the display screen of the AR device, and the fusion of real scenes and virtual objects will be completed. This project is aimed at a 110kV substation of Shanghai Electric Power Company. A BIM+AR model of the substation grounding network was established on the server and handheld ends. The substation BIM models displayed on the handheld end are shown in Figure 3.

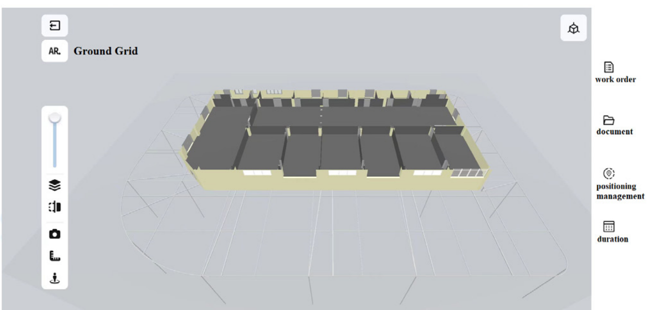

Figure 3. AR client substation grounding network 3D power grounding network building information model

The BIM model of the substation grounding network displayed on the AR handheld terminal is shown in Figure 4. The operation and maintenance personnel configure the AR handheld terminal to the 110kV Qingbai substation site to achieve the fusion of real scenes and virtual objects. The on-site implementation of BIM+AR three-dimensional visualization of the substation grounding network is shown in Figure 5.

Figure 4. The AR device on the AR handheld terminal displays the BIM of the substation grounding network

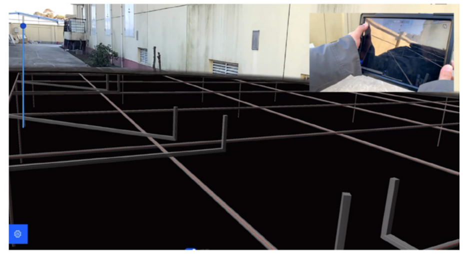

Figure 5. AR equipment displays the integration of BIM and on-site virtual and real of substation grounding network

IV. Example of on-site Implementation of Grounding Grid Excavation

This article takes the excavation inspection of the grounding grid of a 110kV substation as an example to illustrate the technical application of this project. The specific steps are as follows:

The first step is to obtain the characteristic information of the power grounding network. Obtain the design and construction drawings of the power grounding network as shown in Figure 1, as well as the coordinate drawings of each grounding wire in the grounding network, and preprocess the feature information of the power grounding network drawings with unified data format and coordinates. Among them, feature information can include information such as the size, shape, depth, coordinate points, and connection method of the conductors in the power grounding network.

The second step is to establish a three-dimensional power grounding network BIM. Using the extracted feature information of the power grounding grid drawing, establish a three-dimensional power grounding grid BIM as shown in Figure 2. The built three-dimensional power grounding network BIM is configured on both augmented reality servers and clients.

The third step is to register the three-dimensional power grounding network BIM and positioning data. Register the positioning data of each grounding body in the three-dimensional power grounding grid BIM with the positioning data of each grounding body obtained through feature extraction and object detection, and generate a three-dimensional power grounding grid BIM that contains accurate positioning data of each grounding body in the power grounding grid.

Step 4, visualize the 3D power grounding network BIM of the AR client. Display the BIM of the power grounding grid through the AR device of the AR client and integrate it with the virtual and real excavation site of the power grounding grid, as shown in Figure 5.

Step 5, visualize the excavation points of the power grounding network. Set excavation points in the power grounding grid BIM, as shown in Figure 6. The AR device of the AR client can display the positioning data of the excavation points in the camera coordinate system, object coordinate system, and scene coordinate system.

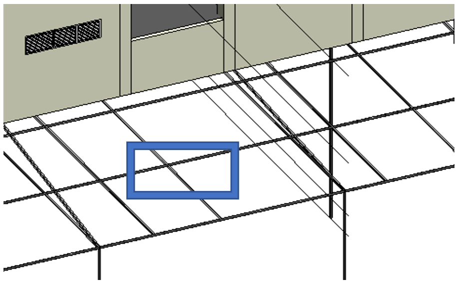

Figure 6. Setting up excavation points in the power grounding grid BIM

Step 6, visualize the on-site positioning and excavation of the power grounding network. Use real-time dynamic measurement equipment to match the positioning information of the excavation site and the power grounding network BIM, and use AR equipment in the AR client to visually display the corresponding on-site excavation points in the power grounding network BIM, as shown in Figure 7.

Figure 7. AR equipment visualization displays the corresponding on-site excavation points in the power grounding grid BIM

According to this application example, the implementation effectiveness of the technology in this article is as follows:

1. Significantly improve excavation efficiency and accuracy. In the past, the excavation time for substation grounding network was generally 1-3 days, which was a blind large-scale excavation; The digital twin technology of the grounding grid status in this project has become an efficient guide for accurate excavation after layout, saving 70% of excavation time.

2. Fully understand the excavation situation. There is data support for the grounding position/burial depth/integrity of the grounding grid.

3. Plan effectively in advance. Targeted excavation locations and planned excavation steps.

4. Reasonably control the excavation period. Reduced blindness and inefficiency.

V. Conclusions

This article proposes a visualization excavation technology for power grounding network based on BIM and AR. The practical application of the technology in the on-site excavation inspection of a 110kV substation grounding network shows that it can meet the application requirements of grounding network work, significantly improve the excavation accuracy, efficiency, and digitalization level of power grounding network.

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