3D Digital Virtual Simulation Application System for Technical Management of Nuclear Power Station Equipment

Yi-Yang Xing, Hua-Bo Huang and Xiao-Ming Yang

Abstract 3D digital virtual simulation application system is designed to improve the risk prevention capability, reduce the maintenance cost and strengthen the refined technical management of nuclear power station equipment. By using virtual reality technology, the assembly and disassembly process, maintenance process and operation principle of nuclear power station equipment can be displayed and simulated in the system. And with the effective association between 3D model, operation data and maintenance data, the system can help professionals to improve and standardize the management of maintenance, quality control and engineering log. This paper expounds the application value and function of the 3D digital virtual simulation of nuclear power station, and presents the technical route of the whole software system.

Keywords Nuclear power station · Technical management of equipment · Virtual reality · 3D · Simulation application

1 Introduction

According to the 13th Five-Year Plan in China, the installed capacity of operational nuclear power station will reach 58 million kW, and those of nuclear power station under construction will reach 30 million kW in 2020, which will increase the nuclear power generation ratio from 2 to 4%. It is expected that the nuclear power generation ratio will be increased to 8–10% till 2030, which indicates nuclear power is an important direction for the development of Chinese energy structure optimization. However, due to the particularity of production object and process of nuclear power, safety problem has attracted a lot of attention. Except the safety

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Y. Xu (ed.), *Nuclear Power Plants: Innovative Technologies for Instrumentation and Control Systems*, Lecture Notes in Electrical Engineering 400,
DOI 10.1007/978-981-10-3361-2_1

measures in the design of reactor, excellent equipment technical management of professionals is also an important factor in ensuring the safety of nuclear power plant.

Equipment maintenance is important work of nuclear power station equipment technical management. There are two kinds of maintenance: one is to ensure the normal operation of system and equipment as designed, and the other one is to repair the failure system and equipment to restore the operational ability as designed. The maintenance of nuclear power station is different from those of the conventional power station or other industrial plants for its large scale, complex equipment, big loss of outage, its importance in nuclear safety and public health protection. Therefore, the technical requirements of equipment maintenance of nuclear power station is very high. The short-term task of nuclear power station maintenance department is to repair the failure equipment as soon as possible to ensure the secure and reliable operation of the units, and the long-term task is to analyze the failure, find out the countermeasures, formulate and improve the practical maintenance plan, and implement the plan.

By using virtual reality technology, combined with database, software, network and graphics technology, 3D digital virtual simulation application system of nuclear power station equipment technical management can establish a 3D digital equipment technical management platform with integrated services, data information and 3D visualization. The 3D display and virtual simulation of equipment structure, disassembly and assembly process of equipment, maintenance process and operating principle can be achieved through this platform, also a comprehensive and effective association among the online operation data, historical maintenance data and equipment basic information can be created in the 3D environment. Therefore, for the equipment technical management with core work of maintenance, both short-term and long-term task, the professionals can understand equipment location, structure, environment, current status and historical maintenance data through the platform in real-time, which helps to formulate quickly and effectively the construction and maintenance, quality control, debugging and commissioning, acceptance check plan and the allocation of related resources, and provides the 3D visualization means for nuclear power station maintenance safety, standardization and speedy and thus to enhance refined equipment technical management and improve the risk prevention capacity of nuclear power station.

2 System Design

A B/S architecture is used in nuclear power station equipment technical management virtual simulation application software. The application function and database are deployed in the back server. Client of nuclear power station network can access the system through web browser, and operate the corresponding function according to the operating authority.

2.1 System Function Design

The 3D digital virtual simulation application software of nuclear power station equipment technical management includes five parts: 3D visualization model, 3D equipment log, equipment maintenance process simulation, equipment operation principle simulation, and equipment operation parameters in real-time 3D display. First, set up visualized models for nuclear power station and all equipment, then develop integrated application software for 3D models and equipment technical management logic, database, and interactive operation, forming a 3D digitized virtual simulation platform, achieving 3D virtual simulation and refined technical management implementation of each equipment structure, principle and maintenance process.

Nuclear power plant equipment management level and technical proficiency is one of the important factors to guarantee the safety of the nuclear power plant, the 3D simulation system of nuclear power plant has a realization of a simple display device or roaming [1]. The system based on virtual reality technology with equipment management business and database data form a complete set of virtual simulation system, and ERP and EAM information systems and docking, can be used for guiding equipment maintenance support sqlserver, Oracle and other mainstream relational database (Fig. 1).

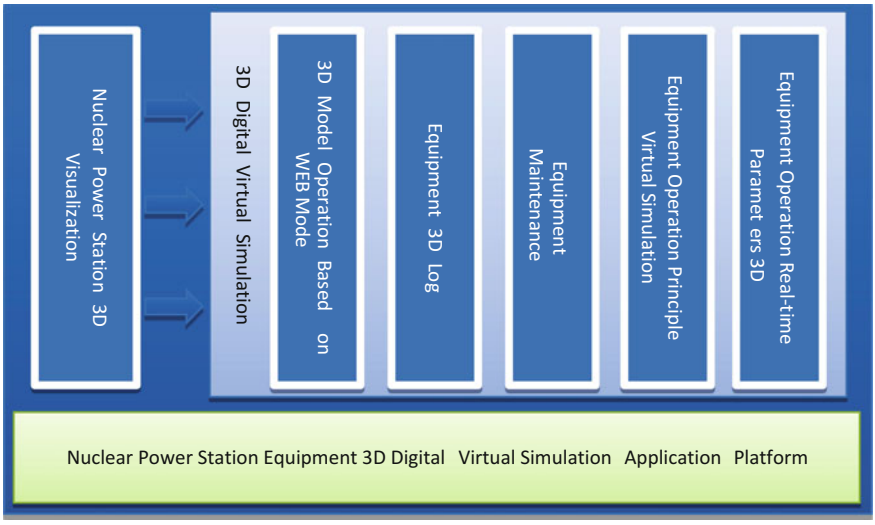

Fig. 1 System function structure

2.2 Technical Architecture

The technical architecture of 3D digital virtual simulation application system of nuclear power station equipment technical management includes the core 3D digital engine, 3D scene editing, IDE integrated development environment and 3D display.

1. Resolve equipment 3D model into 3D image through graphics rendering of 3D engine, the rendering effect is related to the equipment material.
2. Achieve roaming function of 3D scene through scene editing, 3D coordinate and angle of camera controlling and other development of technical parameters.
3. Simulate the wind, steam, smoke, water and other effects in real world through controlling the particle emission rate, emission direction, particle density and other parameters of the particle system in 3D engine by mathematical calculation.
4. Read and modify the related equipment information in relational database through data exchange module to realize the integration of management information system and 3D digital virtual simulation application system.
5. The system support iOS, Android, Window and Mac operating systems, and support web browsers (Fig. 2).

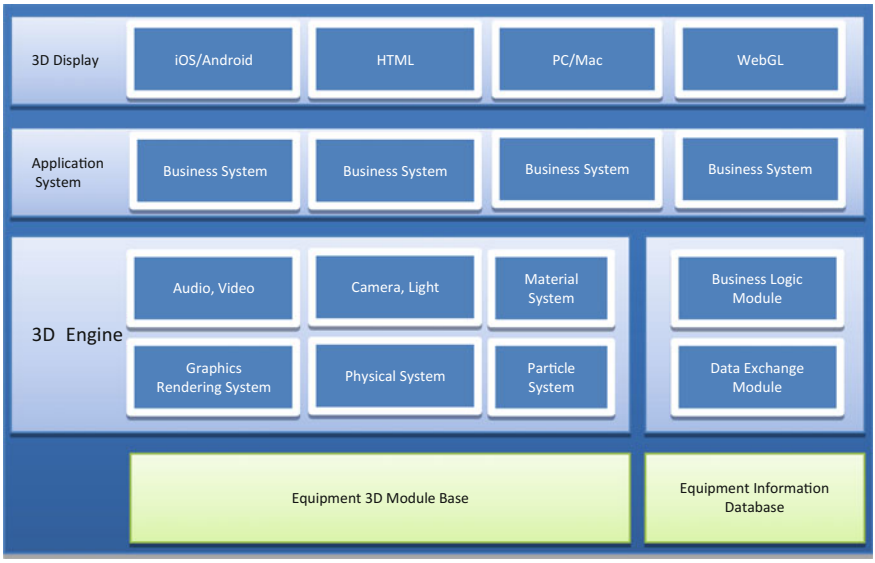

Fig. 2 System technical structure

3 3D Modeling

Nuclear power station is composed of three parts: nuclear island, conventional island and auxiliary system [2]. The physical part includes buildings, systems and equipment. Nuclear power station 3D modeling is divided into plant modeling and equipment 3D modeling. Plant modeling is for understanding plant appearance and nuclear power station layout by scene roaming; and equipment 3D modeling is the base of 3D virtual simulation system application with the scale of 1:1 to the real dimensions of equipment structure, and with the basic modeling primitives of equipment components.

The 3D modeling tool is 3dsMax. The total number and number of surface of models must be fully considered during the modeling. And the model compression, instantiation, mapping and other technical optimization need to be implemented after 3D model is built to ensure the smoothness, stability and realness in the process of using the application system.

4 System Application Function

4.1 The Operation of 3D Model Based on WEB Mode

The operation of 3D model based on WEB mode includes scene roaming and equipment interactive operation.

Different directions of 3D virtual scene is displayed by translation, rotation, push and pull, shake, zoom and combined above methods of camera [3]. The mouse and keyboard can be used as roaming controller and roam freely in the scene, a fixed line can also be set for scene roaming to get best effect of 3D virtual scene.

Equipment interactive operation is the operation of 3D equipment model based on WEB environment, including positioning, zooming, rotation, hiding, perspective, separate display, etc.

4.2 Equipment 3D Log

Nuclear power station equipment 3D log integrates the 1D data, 2D drawings and 3D structure information of equipment together, building the comprehensive, visualized equipment archive, which helps accessing information and review data conveniently and mastering equipment structure, service status at any time.

Equipment 1D data includes specifications, size, manufacturer, spare parts, maintenance record, repair record, etc.; equipment 2D drawings includes equipment structure drawings, installation drawings, photographs, etc.; and equipment 3D information includes equipment 3D visualized model, sound, video, etc.

4.3 Equipment Maintenance Process Simulation

Nuclear power station equipment maintenance process simulation is to reappear or preview the real maintenance process in 3D virtual environment, showing the specific operation method of equipment maintenance visually and dynamically, discovering the spatial relationship of equipment, tools and scene in the process of maintenance, reminding the key operation points and risk precautions, so as to standardize and visualize the maintenance process and improve the efficiency and quality of maintenance work. The specific steps are as follows:

1. Decompose the process of equipment maintenance scientifically and reasonably according to the nuclear power station equipment maintenance procedures, process and safety standards;
2. Build the 3D elements which need to be displayed in maintenance process through 3D modeling, including field, equipment and spare parts, tools and appliance, etc.;
3. Build maintenance simulation animation according to decomposed maintenance process and 3D elements by 3D scene editor, including particle and physical effect and animation control parameters;
4. Develop simulation application function through 3D digital engine, IDE integrated development environment, such as equipment assembly, process jump, pause, text, voice, maintenance record, quality control points, etc.

4.4 Equipment Operation Principle Simulation

Nuclear power station equipment operation principle simulation is to reappear the working principles and effects of each equipment in 3D virtual environment, showing the operation process of the equipment visually and dynamically, providing a visualized analysis method for mastering equipment basic structure and principle, analyzing the key parts and reasons which influence equipment efficiency during operation process.

Nuclear power station equipment operation principle simulation can show the principle of nuclear power station, structure and working mode of the main system and operation principle of single equipment; and can also achieve 3D simulation of nuclear power station equipment operation principle in different conditions, by mapping, texture, particle effect, physical effect, 3D animation and other methods.

4.5 3D Display of Equipment Operation Real-Time Parameters

3D display of nuclear power station equipment operation real-time parameters is to integrate the 3D model and equipment operation real-time data, monitoring and

showing dynamically the operation status of equipment, and alarming and 3D positioning for abnormal data in real time.

Firstly develop one-way access interface program according to the interface protocol provided by nuclear power station DCS system and the equipment field bus control system as well as the information security management regulations; then develop function program through real-time data obtained by interface program in 3D IDE integrated development environment.

5 Conclusion

The system is based on virtual reality technology and 3D digital technology applied in nuclear power station equipment technical management, building a integrated application platform for nuclear power station dynamic virtual simulation, visualizing and standardizing the refined equipment technical management and maintenance process, helping saving maintenance cost, improving equipment technical management and risk prevention ability of nuclear power station. The system can also be used for professional training to improve training quality and equipment operating proficiency.

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