Research on Operation, Repair and Simulation Training Method of Electrical Equipment in Substation Based on Virtual Reality Technology

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Abstract. Virtual reality technology is applied to substation training and a substation training system is established. Based on virtual reality technology, this paper studies the methods of substation electrical equipment operation, maintenance and simulation training. The overall structure of the substation training system is given, and the functions of the substation training system, the system software and hardware environment configuration and the object modeling method are introduced. The research results show that the application of virtual reality technology to construct virtual environment for substation simulation system can greatly improve the realism of substation scene. At the same time, the power system simulation software is connected with the virtual substation to simulate the various operating states of the substation, which brings a technological leap to the substation simulation training work.

1. Introduction
Substation is an important part of the power system. Improving the technical level of substation operators is of great significance for ensuring the safe, economical and high-quality operation of the power system [1]. The operation and maintenance of power equipment are the two main parts of the power system, and the maintenance of power equipment is the core of the normal safe and stable operation of the power system [2]. A large amount of equipment investment in the power system is large, and maintenance costs are high. It is impossible to use physical objects to train personnel, and equipment in production is less likely to be used for training for safety reasons [3]. However, due to the particularity of the power system itself, in the post training of the operating personnel, the operating system cannot be regarded as a test product, nor can the actual operation test be performed on the real equipment [4]. Moreover, it is not allowed to manually set up some accidents for students to observe and deal with. The training system based on virtual reality technology, represented by virtual assembly technology, has been widely used abroad. To promote the power industry to continuously expand the scale of the industry, resulting in the shortage of a large number of transport and inspection skilled workers [5]. Due to the interactive advantages of virtual reality, it is especially suitable for training in special industries, such as power station training, military exercises, etc. The "immersion" of VR refers to the three-dimensional virtual environment established by the computer, which enables the operator to get a full-body experience about the environment.

VR: Virtual Reality (VR) is a very active technology field in recent years. It is an interactive technology developed on the basis of computer graphics, computer simulation technology, man-machine interface technology, multimedia technology and sensing technology [5]. The "interactivity" of VR means that the operator can inspect the entities in the virtual environment and implement corresponding operations through his own skills and professional sensing equipment [6]. It can construct any imaginary environment, and people can communicate with this kind of virtual environment with natural skills. In
recent years, although a large number of new talents have entered the power industry, the actual operation skills are basically lacking [7]. Some training centers established by it still cannot solve the problems of training scale, training subjects and single scenes, and different levels of teachers' practical operations. In China, related applications are still in their infancy [8]. In the power system training industry, a training system based on virtual reality technology has not been found. Therefore, it is necessary to establish a simulation substation with similar actual operation status of the substation for training [9]. At present, most of the training methods of the power system are training simulation systems. The training simulation systems with more applications include power plant simulation, grid operation condition simulation and substation simulation [10]. Therefore, all aspects from power generation and transmission to power distribution need to be operated and controlled by highly trained operators. The severity of any accident caused by human error is incalculable.

2. Virtual reality related research

2.1. The development status of virtual reality technology

Virtual reality refers to an environment that uses a computer and a series of sensing aids to enable people to feel in the real world. It is a seemingly real simulation environment. The electric power training simulation system aims to train the operation and operation personnel of the power system, and requires the simulation training environment to be as realistic as possible. The simulation operation mechanism, equipment status, instrument and signal are required to be the same as the actual system. Make the students feel immersive. At present, the domestic substation training simulation system mainly uses conventional multimedia methods such as wiring diagram, digital diagram, equipment photo and live video as the means of expression, and its realism, presence and expressiveness need to be improved. It can simulate the normal operation, failure and maintenance of the substation and continuously output voltage and current signals. The graphics workstation is responsible for processing information input by trainers, performing logical operations and drawing simulation results, and drawing the drawing results to the output equipment. Therefore, Wuhan Nanrui Co., Ltd. of the State Grid Institute of Electric Power has developed a training system for distribution safety standards based on virtual reality technology to solve the above problems. The results not only increased the learning interest and efficiency of the staff, but also greatly reduced the error rate of novice online. A large amount of equipment in the power system has large investment and high maintenance cost, so it is impossible to train all personnel in kind, and equipment in production cannot be used for training due to safety considerations.

In recent years, the research related to the operation of substation electrical equipment is increasing, which shows that this kind of research is being paid attention to by the majority of scholars. Figure 1 shows the increase and decrease trend of related research in recent years.
2.2. Application of Virtual Reality Technology
The application prospect of virtual reality technology is very broad. It started from the demand of military field and now covers many fields such as education, industry, commerce, engineering design, entertainment, education, medical treatment and computational visualization. The detailed models of primary equipment and its operating mechanism, AC/DC system, relay protection, automatic device and integrated automation system of the substation are considered in establishing the simulation model. The power system virtual environment is a virtual scene generated by a computer. The scene can be not only a reproduction of a real power system application scene, but also a visualization of a design and construction blueprint. Using virtual reality training system, substation environment is three-dimensional and realistic, and human-computer interaction is harmonious and friendly. During the modeling process, the model should be as fine as possible and the storage space should be small. To this end, a variety of flight simulators for simulation training and research design have emerged, which can be seen as the prototype of virtual reality technology. But immersive virtual reality system devices are not only expensive, but each device can only be used by one person at a time. The power system virtual environment is mainly composed of virtual power devices, which can be operated virtually or can visually reflect the results of power simulation. Virtual reality technology is a powerful tool for architectural planning design, decoration effect display, program bidding, program demonstration and program review. It has broad application prospects in the fields of architectural design, real estate and building decoration.

The virtual substation simulation training system should be able to simulate various working conditions and operating procedures of the substation in normal, abnormal and fault conditions, such as equipment inspection, equipment commissioning, adjustment of transformer taps and circuit breaker tripping. The user interacts with the virtual substation through this module and simulates the operation of the substation. The virtual substation simulation training structure is shown in Figure 2.

![Fig.2. Virtual substation simulation training system structure](image)

3. Implementation of the training system

3.1. Overall system structure
The training system includes the following parts: substation tour, tour check, handover demonstration, circuit diagram training, switch operation operation, safety procedure inquiry and accident investigation procedure inquiry. The signal output by the "Power System Simulation" module is processed and sent to the "Input Judgment" module. The power system virtual environment is mainly composed of virtual power devices, which can be operated virtually or can visually reflect the results of power simulation. The current state of the world is determined, and the event provides the node with the ability to receive external messages and send information to the outside world. The screen is a three-dimensional image output without depth information, which is used to observe the training progress. The digital helmet
provides immersive three-dimensional image output for providing a virtual reality environment for trainers. Auxiliary equipment and technology used in underground substations are unique. If operators cannot fully grasp these characteristics, it will seriously affect the safe and stable operation of underground substations and even urban power grids. The database includes model base, defect base, fault base, test bank, database, etc. The model base includes scene model, character model, tool model, action model, etc. Therefore, one object should be established first, and then other objects should be placed with it as a reference. After careful consideration and analysis, it is the best choice to build roads and buildings in the substation first.

The virtual environment is not only the interface between users and computers, but also the ultimate goal of the virtual environment is to pass through the virtual environment. The difference between virtual reality technology and three-dimensional multimedia that we often mention is shown in Table 1.

| Table 1. Differences between VR and 3D Animation |
|-----------------------------------------------|
| VR                                            | Three-dimensional animation                  |
| The virtual environment is composed of digital models based on real data. | Scene pictures are directly drawn by animators according to materials or imagination. |
| The manipulator personally experienced the virtual three-dimensional space and was personally on the scene. | The previously assumed observation path cannot be changed. |
| The operator can feel the scene changes brought by the movement in real time | It can only be demonstrated in one direction like a movie. |
| Supports stereo display and stereo sound       | Non-support                                  |
| With more real and intuitive multi-media Volume display function | Only suitable for simple demonstration function |

3.2. Interaction control
In the virtual scene, two interactive control modes are mainly realized: manipulating virtual objects and roaming virtual people in the scene. Judging whether the state of the virtual equipment changes at this time according to the processed signals and reflecting the change to the virtual substation in real time. The operation of the power system is not allowed to be carried out at will, and accidents in the power system rarely occur. The operating system cannot be used as a test object, and actual operation tests cannot be carried out on real equipment. Moreover, it is not allowed to set up some accidents for students to observe and deal with. Event system is another basic component of scene graph besides hierarchical system. In order to avoid the phenomenon of virtual objects crossing, collision detection and processing are needed. The system uses the collision box detection algorithm to effectively deal with the collision problem. Therefore, the virtual simulation of the auxiliary machine system is a very important development part of the underground substation virtual reality simulation system, and it is also a very important training content for the underground substation operators. The high-precision three-dimensional model is used to project the complete working scenes, real working lines and tools of the distribution line inspection into the spherical ring screen, and achieve the training effect of the students through the holographic three-dimensional projection. For these two interaction modes, the external device input is mainly used. Users can interact with the virtual environment using either a mouse or dedicated hardware device data gloves.

4. Conclusion
The training system provides an advanced training method for the substation operators, which changes the traditional masters' apprentices and traditional classroom teaching modes, and makes the substation operation and training work reach a new level. The system has low hardware configuration requirements for computers and can run on PC and Windows operating system environments, so it is easy to use and easy to promote. The main functions of the system include single-user virtual substation equipment...
learning and virtual substation patrol roaming, and virtual substation equipment disassembly. Moreover, the virtual substation based on PC has lower requirements on computer hardware configuration and has the advantage of being easy to promote. After the maintenance training system is put into use, the trainer can grasp the internal structure of the device and the whole process of maintenance in a short time, and improve the inspection efficiency, reduce the waste, and reduce the pollution while ensuring the quality of the inspection. With the continuous development of computer technology, substation simulation training system has more powerful functions and more obvious training effects. The introduction of this system can change the training mode of the electric power industry, replace the actual training center with software and hardware systems, provide safety guarantee for electric power training, save the training cost of the electric power industry, and have better economic benefits and practicability. Due to time and technical limitations, there is still room for improvement in some aspects.

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