Research on Skill Training of Relay Protection Device Based on Virtual Reality Technology

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Abstract. Aiming at the problem that operation and maintenance personnel and new employees have insufficient experience in substation secondary equipment, especially the secondary circuit operation, this article introduces the current domestic and foreign research status of virtual reality technology. With the goal of enhancing the fun of substation secondary equipment training and improving training efficiency, the overall research ideas and content are proposed, and the application function framework of virtual reality technology is explained.

1. Introduction
The safe operation of high voltage transmission and transformation equipment has become an important factor affecting the safe, stable and economic operation of power system. The number of high-voltage switches in the power grid is huge, which plays the role of control and protection. When it breaks down, it will directly cause the power grid accident or further expand the accident, causing considerable economic and social losses.[1-3] How to effectively detect the working state of the high-voltage switch, find the early defects of the switch in time, deal with the defective parts in advance, and prevent the switch explosion and other malignant accidents, is of great significance to ensure the safe and reliable operation of the power grid.

High voltage circuit breaker plays a very important role in modern power system. It is the fundamental guarantee for the safe and stable operation of the system, and also the primary protection when the system fails. Therefore, the performance test of high voltage circuit breaker is of great significance for the safety of the system. The performance test of high voltage circuit breaker needs to be carried out in the process of circuit breaker breaking.[4-5]

Traditional relay protection skills training is mainly carried out in the relay protection laboratory or the substation site. It is carried out in the form of a teacher and an apprentice. The training is affected by time, place, on-site safety control and training teachers' technical level, it is impossible to achieve multiple repetitive drills, so that trainees cannot grasp the initiative of training, resulting in great differences in personal technical level, greatly reducing training efficiency and training effects. In addition, the trainees cannot simulate targeted training in various complex and unexpected environments, and their adaptability and related processing skills cannot be effectively improved. In the new background of relay protection devices with many models, many manufacturers, complex technology and fast update speed, it is very urgent to study virtual (VR) simulation training and develop a VR-based secondary equipment simulation and training system.
2. Research status at home and abroad

Virtual reality is the ultimate application form of multimedia technology. It is the crystallization of the rapid development of computer hardware and software technology, sensor technology, robot technology, artificial intelligence and behavioral psychology. It mainly depends on the development of many key technologies, such as 3D real-time graphics display, 3D positioning and tracking, tactile and olfactory sensing technology, artificial intelligence technology, high-speed computing and parallel computing technology, and human behavior research. With the development of virtual reality technology, the real realization of virtual reality will cause great changes in human life and development. People wear stereo glasses, data gloves and other special sensing devices, face a three-dimensional simulation of reality, it seems to be in a three-dimensional visual, auditory, tactile and even olfactory sense of the world, and people can interact with this environment through human natural skills and the corresponding facilities.

Some foreign research institutions have carried out more in-depth research on the level of virtual reality technology. Among them, Professor A.S. MALOWANY from the Department of Electrical Engineering of MCGIL University in Canada, and others have developed virtual reality operator training system ESOPE-VR, which is applied to power system training on graphics workstations. The system establishes a three-dimensional computer simulation environment of the power station, which can simulate various sounds of the power station operation and recognize the voice commands of the operator. It can simulate the power station environment and equipment actions through interactive multimedia interfaces such as pictures and videos. The Computer Department of the University of North Carolina (UNC) in the United States developed a personalized and portable visualization system based on the virtual reality research group. The system allows users to roam and interact with object models with complex meanings, while receiving actual visual, auditory, and tactile feedback graphics with a refresh rate of 25 frames per second. The GVU of Georgia Institute of Technology in the United States has also completed the virtual geographic information system project, which uses geographic information system (GIS) for military visualization and application integration of simulated virtual environments.

![Image](image.png)

Fig. 1. Wiring diagram of electric stopwatch measuring time interval.

Figure 1 is the wiring diagram of the time interval measured by the electric stopwatch. Many domestic research institutions and universities are also carrying out the research and application of virtual reality technology, including the Virtual Reality and Visualization New Technology Research Laboratory of the Department of Computer Science and Technology of Beijing University of Aeronautics and Astronautics, which can provide real-time 3D dynamic database, virtual reality demonstration environment, virtual reality system for flight training, and virtual reality application system development platform. The State Key Laboratory of CAD&CG of Zhejiang University has developed a desktop virtual building environment real-time roaming system. The Institute of Intelligent Manufacturing and Control of Wuhan University of Technology uses virtual reality technology for mechanical virtual manufacturing. In addition, in order to overcome the limitations of traditional training, literature [6-8] built a substation relay protection simulation system based on virtual reality technology, so that trainees can not only intuitively understand the appearance and basic operations of the equipment through human-computer interaction, but also check the action of relay protection device under different faults through fault setting. Literature [7-10] builds simulation experiment model with MATLAB/Simulink, applies virtual experiment technology to basic experiment teaching of electrical engineering, and completes the purpose of traditional experiment teaching. Literature [11-12] connects the real relay protection device with the virtual power system model to realize the virtual and real hybrid
simulation. This paper proposes an overall scheme that combines virtual reality technology with the simulation of the secondary circuit of relay protection. The equipment form can be changed at any time through interaction. At the same time, the system will feedback the changes and serious consequences brought by relevant operations, so as to achieve the purpose of teaching, self-training, competition, examination and practical training.

3. Overall research ideas
Virtual reality technology is used to reproduce the operating environment of the substation and its various parts. The environment has a highly consistent on-site immersion with the actual operating conditions of the substation, so that the trainees will behave in terms of feedback from perception, operation, or action processing. It is highly consistent with the real reaction. Relevant training guidance can be organized at any time according to their actual needs, trainees and other relevant personnel can conduct training exercises, conduct exercise evaluation and improvement. Trainees can also carry out unlimited repetition exercises spontaneously, so that the trainees are always in the leading position in the training, master the initiative of training, and greatly improve the efficiency and effectiveness of the exercise. At the same time, with the help of virtual reality technology, trainees can put themselves in various complex and unexpected environments, so as to carry out targeted training and improve their resilience and related processing skills. This can quickly and effectively improve the professionalism and technical level of the staff.

4. Overall research content
This article focuses on the insufficiency and scalability of substation secondary equipment operation and maintenance technology in operation and maintenance training and operation and maintenance work. In order to ensure the operation safety of secondary equipment, improve efficiency and skilled skills, the relevant research based on VR virtual reality technology is carried out. The main research contents include the following five aspects.

A. Research on establishing the model of relay protection device with computer technology
The most realistic response is needed to simulate the presentation of the action behavior of the protection device when the external electrical quantity is input. The realistic three-dimensional immersive scene technology is adopted to truly reflect the actual working state of the equipment. The purpose is to make the personnel familiar with the complex process and operation process, standardize the process and cultivate the skilled field personnel.

B. Computer technology is used to establish a model to simulate the operation of the protection device, the connection relation of the pressure plate and the wiring of the secondary circuit
It presents the action behavior of the protection device and the change of the electrical quantity of the secondary circuit when the system parameters change, truly reflects the secondary circuit wiring mode and wiring effect of the secondary equipment on site, and realizes the inspection items of the secondary circuit and terminals. Realistic simulations are carried out on the actual field problems caused by the abnormal wiring of the secondary circuit, so that the students can have a deeper understanding of the logical relationship between the secondary circuit of the substation and the control system. Provides a typical secondary system simulation model in the power system, and has functions such as modification and expansion, protection device, secondary circuit failure, including: protection device failure, protection power failure, protection refusal, protection misoperation, protection of AC current/Voltage circuit disconnection, high frequency (optical fiber) channel abnormality, wrong setting, wrong position of pressure plate, small switch, plug-in unit, wrong secondary wiring, AC series connected to DC circuit, secondary circuit fuse blown, secondary circuit small switch mistakenly tripped, TA/CT disconnection, short circuit, grounding, phase sequence error, secondary circuit open circuit, TV/PT disconnection, short circuit, phase sequence error, secondary circuit short circuit, relay contact sticking, refusal to move, poor contact, secondary circuit The loop is grounded, disconnected, etc.
C. Research the algorithm for interaction between VR and external data

Research on data interaction algorithms and software development toolkits, and establish a collection of application software and development tools for specific software packages, software frameworks, hardware platforms, operating systems, etc. An SDK can be a set of specialized files that provide an application programming interface API for a programming language, including functions: including practical tools for debugging and other purposes, including sample code, supporting technical comments or other basic data sources to clarify doubts. Technical support documents, including complex hardware devices that can communicate with a certain embedded system, at the same time, research and development API, namely application programming interfaces, are some pre-defined functions that provide applications and developers to access based on certain software or hardware. The ability of a set of routines, without access to the source code, to understand the details of the internal working mechanism. All applications that are executed underground in the windows work environment can call the windows API.

D. The human-computer interaction between operator and VR is studied

With the help of the VR virtual exercise system, relevant training guidance can be organized at any time according to their actual needs, trainees and other relevant personnel can conduct training exercises, conduct exercise evaluation and improvement. Trainees can also carry out unlimited repetition exercises spontaneously, so that the trainees are always in the leading position in the training, master the initiative of training, and greatly improve the efficiency and effectiveness of the exercise. At the same time, with the help of virtual reality technology, trainees can put themselves in various complex and unexpected environments, so as to carry out targeted training and improve their resilience and related processing skills. This can quickly and effectively improve the professionalism and technical level of the staff.

E. Simulation system development and prototype development

Using virtual reality human-computer interaction technology, software development kit based on the unified three-dimensional modeling system and HTC VIVE and other virtual simulation technologies to realize the human-computer interaction between 3D scenes and VR virtual reality helmets and operating handles. Real-time communication with the mathematical simulation model is realized through relational database and communication thread, to maintain the consistency of data and status, to view and operate the loop of the secondary equipment, and the system guarantees the simulation operation function consistent with the scene. Users can construct various expected system working conditions and fault conditions, and conduct test experiments on the relay protection system. The power system is a huge and complex system. According to its inherent physical laws, mutual relations and actual functions, the complex and various devices in the power system can be classified into several types. Establish a mathematical model based on its internal mechanism. According to the actual system, apply a general algorithm to a specific device, and configure each input, output, and coefficient to reflect its characteristics. And connect them one by one according to material flow, control information flow, and data communication.

5. Functional framework

The power grid dynamic analysis calculation program should be able to accurately simulate the various operation modes of the power grid and the system change process under the accident state, including automatic topology analysis, dynamic power flow calculation, fault analysis calculation, frequency calculation and other functions. Based on this, the power grid simulation should achieve the following main functions:

A. The normal operation and maintenance simulation of the secondary equipment of conventional substations includes the status display of the secondary equipment under normal operation, the adjustment of the operation mode of the power grid, the operation simulation of the secondary equipment, the secondary action behavior in the event of a power grid failure, and the guidelines for accident handling.

B. Establish a library of secondary equipment defects, and simulate the abnormal state of the secondary circuit, including CT secondary circuit disconnection, short circuit or multi-point grounding abnormal simulation, PT secondary circuit disconnection, short circuit (air switch trip) abnormal simulation, trip, and close Abnormal simulation of gate circuit and monitoring, abnormality of main
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protection fiber channel, abnormal simulation of DC grounding, abnormal simulation of switch circuit of switch and multimeter, etc.

C. The scope and extent of the simulation are subject to the actual equipment, functions and requirements of the simulation target site and the actual operating conditions of the site.

The function of VR mainly relies on the Unity3D engine as the platform, combined with the HTC VIVE-VR glasses as the tool, and connects to the background database to achieve the purpose of communication, thereby completing the interactive information. Unity3D connects to VR glasses through Steam SDK and drives the VR handle as an interactive tool.

6. Conclusion

Virtual reality is widely used in medicine, entertainment, military and aerospace, interior design, real estate development, industrial simulation, emergency deduction, games, geography, education, hydrogeology, maintenance, training and training, shipbuilding, automobile simulation, rail transit, energy field, biomechanics, rehabilitation training and digital earth.

The application of virtual reality technology to the research on skill training of relay protection devices can effectively solve the problem of providing relay protection operation and maintenance personnel and new employees with a platform for intuitive understanding of the operation during the load test. In addition, it provides a visual and real sense of the scene to make up for the problems of young employees' lack of experience in the operation process of the relay protection load test. In addition, it can increase the fun of training secondary equipment for relay protection, at the same time enhance the training effect, and effectively improve the training efficiency, which is conducive to the promotion and application of training. Through the actual simulation of the field environment, the proposed method can effectively improve the working ability of the staff. So that the staff in the process of work more familiar with the condition of the equipment, so as to reduce the personal safety risk that may occur at any time in the work. In the future, this method can be extended to all kinds of electric power fields, which has extremely important practical significance to reduce the safety risk of electric power operation.

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