# Development of Virtual Reality Simulation Training System for Substation

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**Abstract.** In order to improve the reality of substation training environment, a 3D training system is developed to train operators' operating skills and ability to deal with accidents by means of a virtual reality environment. Functions, architecture, key technologies and application of the substation simulation training system are described in this paper. It has been applied to several electrical power companies and training colleges. The result shows that the system can simulate the running process of substation vividly and improve the training effect. There is no need to enter the substation to carry out the actual operation practice.

## Introduction

Substation is an important part of the power system. The correct operation of the substation is the precondition to ensuring the security and stability of power system. The solid professional skills of power system operators play an important role to ensure the security of power system. So it is necessary to improve the professional skills of the power system operators [1]. Substation is a high-risk site, accidents may occur at any time. The operation of the power system is not allowed to practice at will on the real equipment. It is impossible to set up some accidents artificially to observe and learn for operators. Therefore, in order to improve the operator's ability to solve problems and deal with accidents, it is particularly important to establish a virtual simulation environment to simulate the operation of substation [2] [3].

The simulation for power system training has been developed for several decades, there has been a simulation of power plant unit abroad in the 1970s.The Japanese electric power company also developed the substation simulation system in the end of the 1970s. The earliest power training system based on computer developed in the United States until 1971 [4].However, Canada and other countries developed the simulation training systems which were based on virtual reality technology in 1990 [5] [6]. In China, the research on the substation simulation system began in 1970, the first substation simulation training system using two-dimensional images was developed in 1990 [7]. At present, the majority of training systems are mostly based on the text, wiring diagram, digital table and other ways to simulate the practical operation. These training systems are not real enough [8] [9].

In order to adapt the development of the situation and meet the training needs of power system, it is imperative to improve substation operator’s comprehensive abilities and prefect the substation simulation training system [10] [11]. So a 3D training system is developed to train operators' operating skills and ability to deal with accidents by means of a virtual reality environment. Functions, architecture, key technologies and application of the substation simulation training system are described in this paper. This system can provide a reference for the development of other simulation training system.

## Functional Requirements Analysis

Substation simulation training system is developed for the substation operators, so the system is designed around the daily work of the operators. As shown in Fig 1, the functions of substation simulation training system contain four parts: learning, exercise, exam, system management.

 

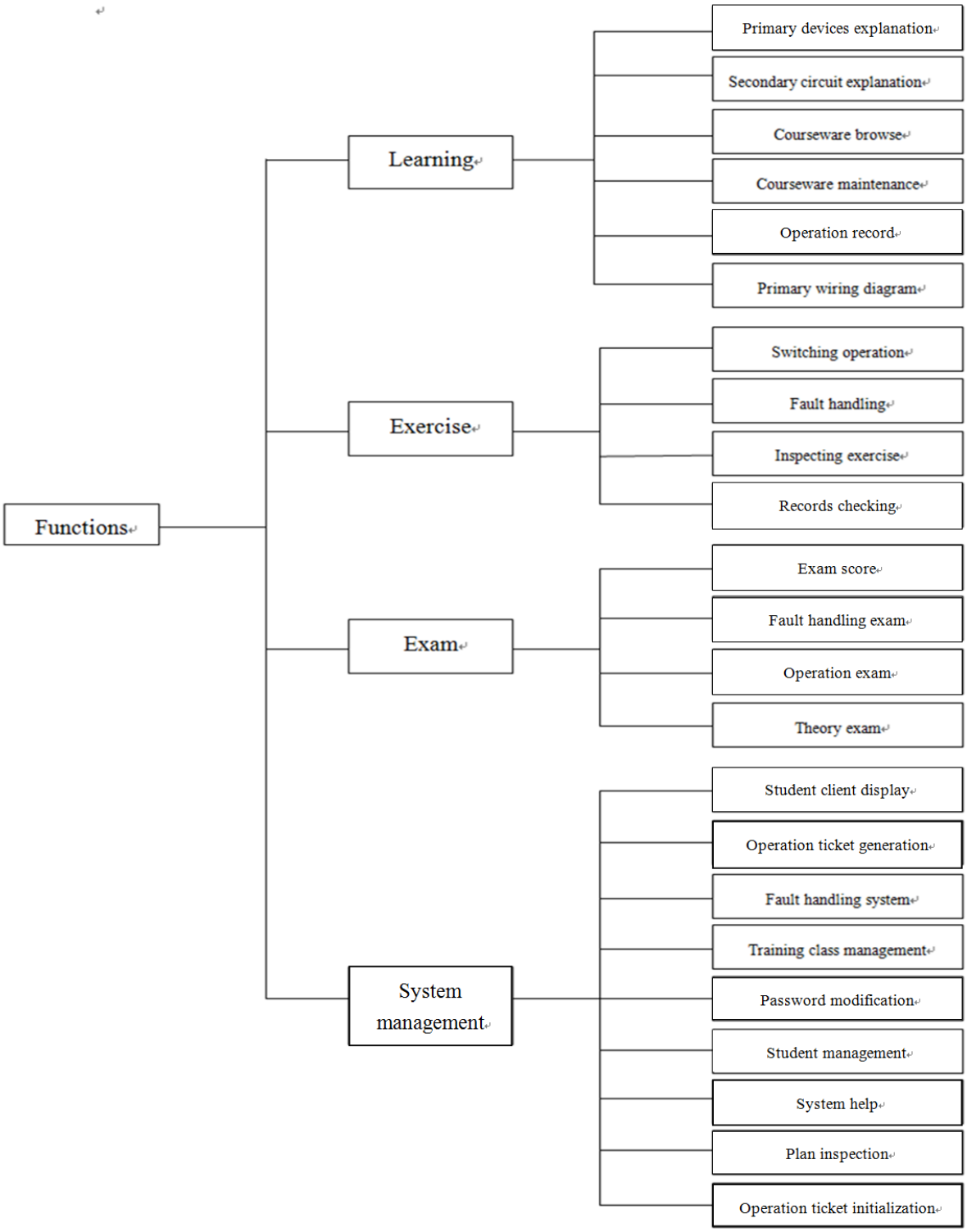


Fig.1 training system function diagram

Learning: Learning function is mainly to explain the theoretical knowledge. The theoretical knowledge is explained by using the form of courseware. After entering this module, the courseware will be loaded, students can learn the courseware independently.

Exercise: During the exercise, the operation of the student can be recorded. They will be able to view the results of the operation after the exercise.

Exam: Examination system uses C/S architecture. There are two roles of login, teacher or student. After the students finishing the exam, the results will be sent to the teacher automatically. The teacher can score the operation results of the students.

System management: System management function can view, store, manage, update and maintain basic data. For example, after entering this module, the teacher will be able to see the connection

status of each student, modify password, generate operation ticket, etc.

## Software Architecture Design

The mode of this substation simulation training system is pure software, rather than disc type which is based on hardware. As shown in Fig2, software architecture is divided into five layers: foundation environment layer, data layer, data interaction layer, presentation layer (include foundation layer, core layer, logic layer), application layer. The hierarchical architecture allows users to complete the corresponding operation according to the different needs.

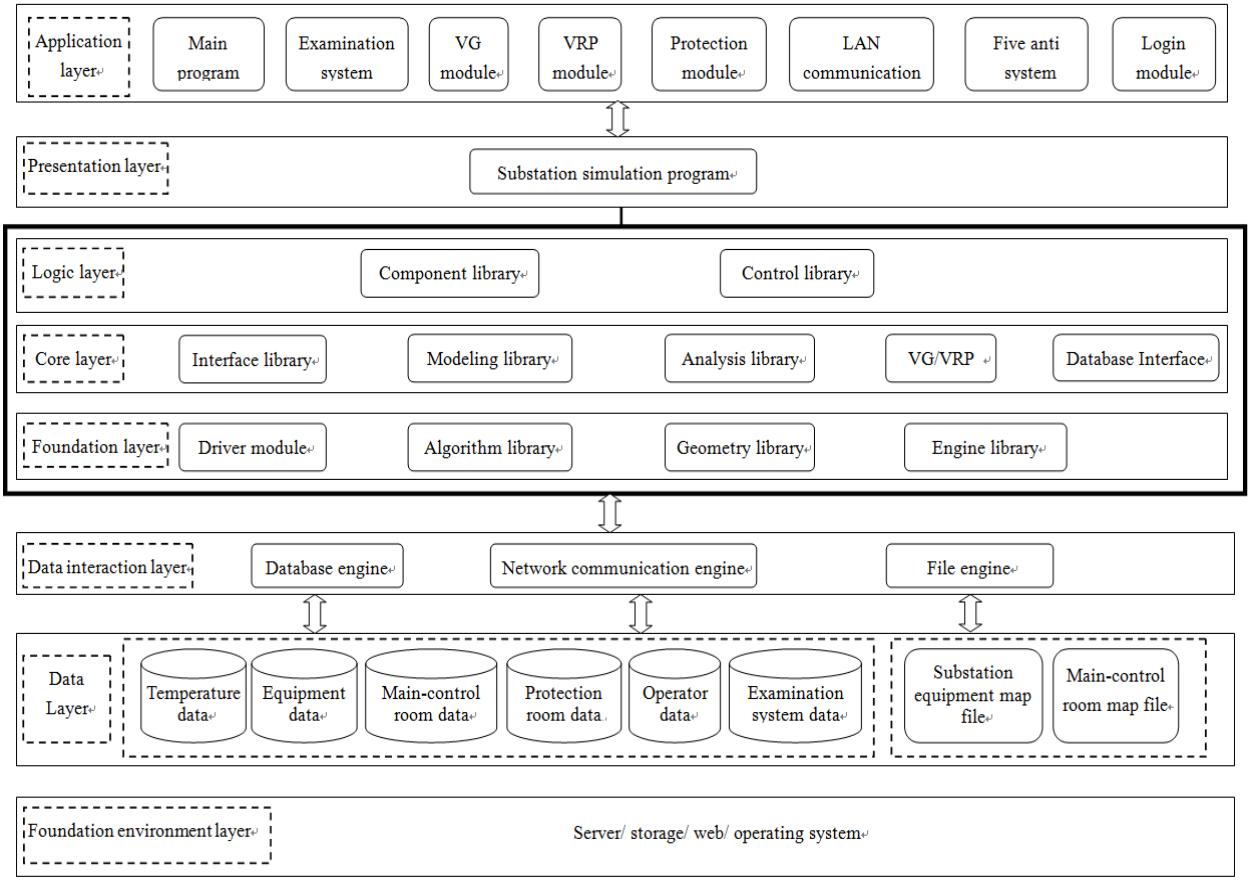


Fig. 2 software architecture

Data layer: It is divided into database and map file. The database contains the initial state information and data, and data management is implemented by SQL server 2000. The information of the equipment is stored in the map file.

Data interaction layer: All of the modules communicate or access relevant data through this layer. Network communication uses TCP/IP protocol.

Presentation layer: Include foundation layer, core layer and logic layer. Using the relevant library of core layer, foundation layer drives the operation of the program, combining with the programs that need to be written. In logic layer, a large number of controls and components are used to display the program through the interface library. The program is made to be visualized, operable, and displayed to the user through the presentation layer.

Application layer: The required function is realized by the combination of the module

## Key Technology Implementation

**Establishment of Virtual Substation Model**. Virtual reality (VR) technology is an interactive technology between human and machine to simulate a variety of perceived behavior vividly. Its purpose is to establish a highly realistic simulation environment [12] [13]. VR technology is applied to the substation simulation training system to simulate and construct the reality environment, and

enhance the reality and immersion perception of substation scene [14].

Using virtual reality modeling language (VRML) to establish virtual substation can make the equipment and operating conditions more realistic. VRML is a file format for the transmission of 3D data on a network, which is defined by the ISO. To realize the interactive function between the operator and the Virtual Substation, firstly, the VRML is used to establish the virtual power equipments such as transformer, circuit breaker, reactors and other equipments, and then put them into the same scene. That is the initial realization of the virtual substation modeling.

Fig. 3D scene of virtual substation

**Relation between 3D Scene and Primary Wiring Diagram.** Two parts are included in the system: 3D scene and primary wiring diagram. They are connected by communication. 3D scene is developed by Virtual Reality Platform (VRP) and VC++ for controlling script-driven. Primary wiring diagram is realized by Visual Graph (VG) and VC++ for controlling script-driven. Fig4 is the relation diagram.

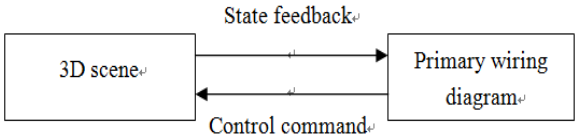


Fig. 4 3D scene and primary wiring diagram relation

For example, 1.Primary wiring diagram controls 3D scene: in 3D scene, all devices are enabled remote-control by default. Giving instructions in the primary wiring diagram at this time, 3D scene will do the corresponding reaction according to the received instructions, such as fault setting, line maintaining and so on. 2. 3D scene feedbacks primary wiring diagram: when a knife gate switch on or switch off in 3D scene, the primary wiring diagram will show the state of switches according to the feedback of 3D scene.

## Application Analysis

The substation simulation training system designed in this paper has been applied to several electrical power companies and training colleges. Illustrated by the example of some training college, this system can be operated on one machine or a LAN which is made up of multiple workstations. The simulation training system under network mode can constitute network room: one teacher machine and a number of student machines. The current MAC of IP and student name can be searched by LAN IP address to add. The teacher can manage all of student machines and choose the student machines to power-on, power-off or restart after adding. Fig5 shows the student management interface. Fig6 shows the interface that students practice switching operation.

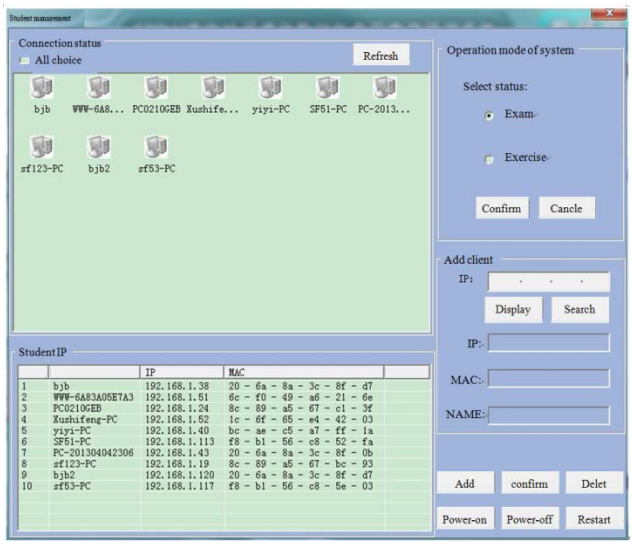


Fig. 5 student management interface

Fig. 6 switching operation

Following advantages are also found during the process of application.

(1) The system can show the running process of substation vividly by using text, 3D animation, sound and other forms of expression, which helps to mobilize the enthusiasm of students and improve the training effect.

(2) Design of 3D scene based on drawing scale, the simulation effect is almost the same as the real field devices. It has improved the authenticity of the scene greatly.

## Conclusion

A 3D training system is designed for training operators' operating skills by using a virtual reality system has been studied out in this paper.

This system allows full viewing of any of the substations in the power supply network, allowing navigation into the virtual world and interaction with the elements. Each of the substation components has been constructed in the simulation model, so the complete functionality of the substation can be simulated [15]. This system has the characteristics of realistic rendering and vitality because of the combination of the virtual reality technology and the simulation training system. In particular, training effect is improved and training costs are reduced through this system. The system software can run on Windows XP, Windows 7 and other 32 bit operating systems, so it is convenient to use and easy to popularize.

With the development of technology and improvement of human skills, power system continues to expand the scale. In order to adapt to the development of the new situation, it is imperative to improve the simulation training system. Simulation training system for substation will be more versatile and realistic under the leadership of advanced technology.

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