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# Research on Simulation System of UHVDC Transmission

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***Abstract*—Skill training of UHVDC Operators is becoming increasingly important with the rapid construction of UHVDC projects. It is necessary to build a simulation system to meet the training needs. This paper presents a fully digital software simulation program. The entire system can run on a computer, which includes the Operators Work Station system, the primary equipment and the second equipment scene simulation, while in the background of AC/DC hybrid power grid and control & protection system simulation. This simulation system provides training for the operation of the UHVDC converter station with the simulation of the whole scenes of Jinping - Suzhou UHVDC transmission project as the prototype of the training system.**

***Keywords-UHVDC transmission; training simulation; training***

## I. INTRODUCTION

UHVDC transmission system is an important part of the interconnection of large power grid, bearing more than 70% of the cross-district power transmission. The operation and management level of the UHVDC transmission system directly affects the transmission capacity and production safety of the inter-regional power grid. The domestic UHVDC transmission projects don't have a long time to accumulate enough experienced operation personnel and cannot meet the rapid development of UHVDC. There is urgent need for a set of efficient, comprehensive, systematic professional platform for UHVDC operation training.

## II. DESIGN

The simulation system is in form of all-digital software simulation, and the entire simulation system can run on one computer. The advantage of this design is the small footprint, requiring only one computer to carry out training. It can also be installed in the computer classroom, where dozens of people (determined by the number of computers within the classroom) can take training at the same time. Therefore, the simulation system can not only be easily deployed in the UHVDC converter station to carry out in situ training, but also can be installed in the training institutions to carry out centralized training in the classroom.

The software of the simulation system includes some scenes simulation of the UHVDC converter station, the primary equipment scene simulation, the second equipment scene simulation, the OWS simulation and the simulation of the converter and the station control system. The primary equipment and the second equipment scene simulation are in the form of virtual three-dimensional scene. OWS system simulation is in the simulation system to achieve with the real OWS system consistent "four remote" function [1]. The above is the simulation system software interface, and the surrounding power grid simulation and control & protection system simulation are the central parts of the software, responsible for power flow calculation and logic operations.

## III. SIMULATION SYSTEM HARDWARE STRUCTURE

Localized training mode requires only one computer, which do not need the support of network equipment, as long as the appropriate computer hardware is adopted. This section focuses on the hardware structure of the centralized training mode.

### A. Computer Hardware

Computer main hardware configuration is as follows: CPU, Intel i7-2600, 3.4 GHz; graphics, AMD Radeon HD 6450; memory, 8GB; hard drive, 100GB; monitor, 21 inches. As the operating system using windows7 flagship version, when the simulation system is in operation, CPU occupies less than 45% and the memory occupies less than 50%.

The computer is required to use discrete graphics for the virtual 3D scene of the simulation system. Simulation software includes the interfaces of OWS system simulation and virtual three-dimensional scene simulation, therefore, a dual-screen design was used, to avoid frequently switching the screen.

### *B. Network Structure*

The instructor and the student machine are deployed in the same local area network and connected through a Gigabit local area network. Normal network traffic is less than 120kbps; the use of Gigabit network is mainly to facilitate the installation and upgrades of the simulation system through the local area network, but also taking into account the possibility of classroom deployment of other software systems. The network structure is shown in Fig. 1.

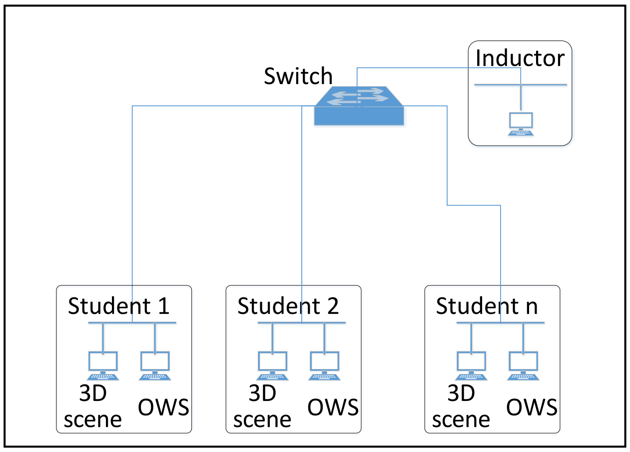



Figure 1. Simulation system hardware structure diagram.

## IV. Simulation System Software Structure

Simulation system software structure is shown in Fig.2. Interactive coordination simulation support platform is the basis of the system support software for each simulation module to provide plug and communication management services.

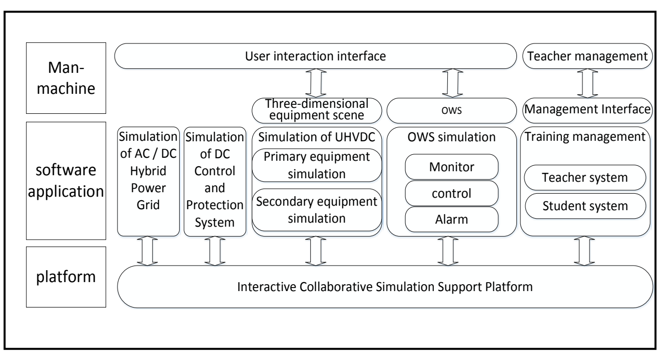



Figure 2. Simulation system software structure diagram

The functional application layer of the system mainly includes two parts: simulation application module and simulation management module. Simulation application module is the core of the system, to achieve the operation of UHVDC converter station simulation function. The simulation management module is a system management software developed for the simulation system, which supplies management of the start and stop of the simulation system and the management system for the teachers. Based on the standard interface provided by the operational support environment and the characteristics of the converter station, the simulation application of the converter station is carried out to form a three-dimensional scene including AC/DC hybrid grid simulation, control and protection system simulation, UHVDC converter station Simulation [2], OWS system simulation and teacher management system of all-digital interactive training simulation system.

The man-machine interaction layer is an important place for the interaction between the application system and the simulation software. It mainly includes the grid monitoring interface, the converter station's primary and secondary scene interface, the OWS simulation interface and the system teacher management interface. Through these man-machine interfaces, trainees can carry out remote control, equipment inspection, fault handling and other operations, the instructor can execute the adjustment, fault settings and other operations, which achieve the whole scene, the whole process of training.

AC/DC hybrid power grid simulation and control protection system simulation provides power flow calculation services to achieve DC transmission control function simulation and protection function simulation for the OWS to provide telemetry, remote information[3].

## V. Simulation Modeling Method

UHVDC transmission simulation training system is mainly composed of AC/DC hybrid grid simulation, control and protection system simulation, UHVDC converter station three-dimensional scene simulation and OWS system simulation. As shown in Fig. 3.

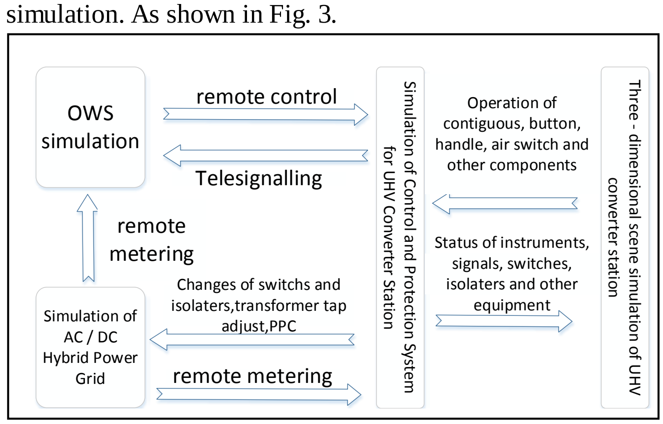



Figure 3. The relationship between the simulation modules

### *A. Simulation Model of AC / DC Hybrid Power Grid*

The system is based on the main grid of Central China Power Grid and East China Power Grid. Considering all the DC links between the power grids and the important power plants and substations, while the rest is equivalent in which way the AC/DC grid simulation model is established [4]. Simplified grid structure is shown in Fig. 4.

In the AC power section, there are 50 sets of generating units, 60 500kV AC substations and 160 500kV transmission lines.

In the DC power section, there are three ±800kV transmission lines (Fulong-Fengxian, Yibin-Jinhua and

Jinping-Suzhou), four ±500kV transmission lines (Longquan-Zhengping, Gezhouba-Nanqiao, Yidu-Huaxin) Based on the above-mentioned simulation range of AC/DC power grid, the detailed simulation model of the Jinping-Suzhou UHVDC transmission system is established.

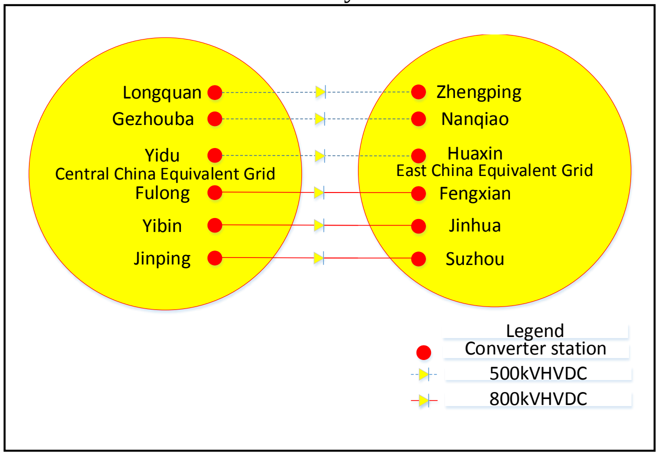



Figure 4. Simplified AC / DC equivalent

## B. UHVDC Control & Protection System

### 1) Control system

The basic principle of DC transmission system is to control the conduction and shutdown of the commutator components, in order to achieve AC and DC conversion. Change the trigger angle, DC line will produce a different current, thus changing the power transmission. In addition, for slow voltage variations, the trigger angle can be maintained near the rating by adjusting the tap of the converter transformer [5]. The simulation system does not need to consider the rapid change process of milliseconds. The simulation system establishes the steady-state model of the DC transmission system and the control system to realize the basic control model of the trigger angle control value from the power/current target value. On the basis of this, according to the logic of the control system of the converter control system, the logic of the engineering control software can be used to simulate the interconnection between the DC equipment, the control operation, the converter variable control, the converter control, the operation mode control, overload control, open line test, pole power control, reactive power control, voltage and angle reference control, etc., to support all the typical converter station operations.

### 2) DC protection system

The DC protection system adopts the simulation method based on the logic judgment to establish the protection strategy library of various faults of the DC system. When the fault is simulated, find it in the policy library based on the fault name, and then perform the appropriate protection policy. This approach can increase the protection strategy as needed, and does not require complex fault calculation and start-up links, with good flexibility and efficiency. Fig. 5 is the program processing flow comparison between the value start method based on the principle of protection (1) and method based on the logic judgment (2).

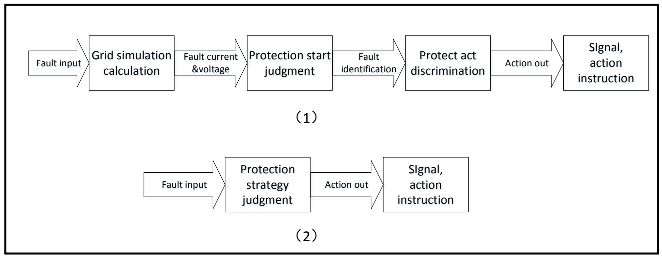



Figure 5. Comparison of two protection simulation processes

The DC protection system simulation model includes converter protection, pole protection (including pole, pole bus, neutral bus, DC line, DC filter, smoothing reactor and DC switching field device), bipolar protection (including double neutral and ground poles), converter valve protection, converter AC bus and converter transformer protection[6]. The system can flexibly set faults such as high or low voltage converter, converter valves, pole bus, neutral bus, DC filter and DC transmission line according to the characteristics of running UHVDC operation.

## C. Three - dimensional Scene Simulation of UHVDC Converter Station

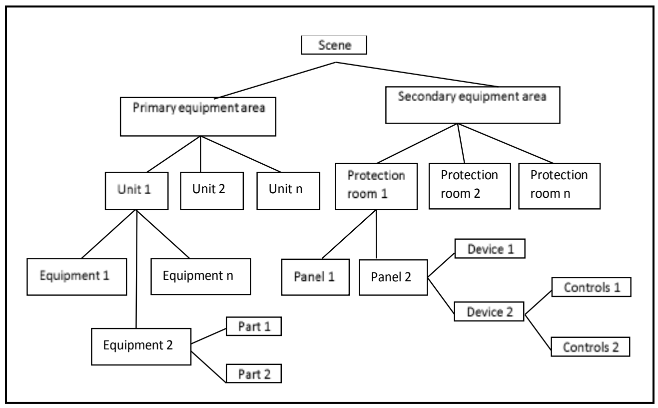


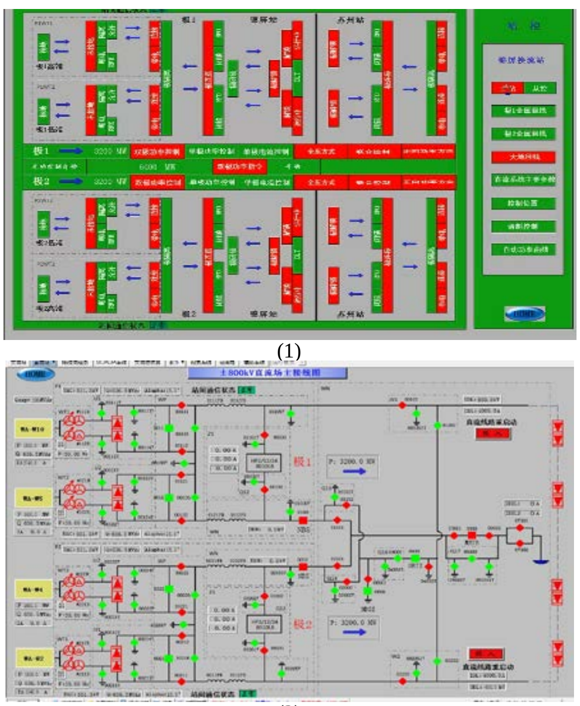

Figure 6. Three - dimensional scene model N - tree

In the converter station simulation, the converter station of the primary and secondary equipment is in form of three-dimensional scene. In order to solve the problems of cumbersome and time consuming in the development of 3D model, according to the highly repetitive nature of 3D model control, a visualized component modeling system is adopted. The modeling system mainly uses the equipment assembly tool, the unit assembling tool and the scene assembly tool to combine the developed component library, the equipment library and the unit library, according to the component generating device, the equipment generating unit, the unit generating the scene to complete the whole three-dimensional scene. The formation process of the 3D system is shown in Fig. 6.

Based on the three-dimensional virtual scene technology, an interactive full-3D virtual scene of the UHVDC converter station, including the primary and the secondary equipment, was developed to realize the free roaming, equipment operation and equipment inspection of the virtual scene. The fractal and particle system simulated explosion, smoke, discharge arc and other special effects and rain and snow and other climatic conditions, to achieve a full scene simulation and enhance the training effect.

### D. *OWS System Simulation*

The OWS monitoring system of the converter station is an important place for the converter station monitoring, operation and analyzation [7]. It is the command center for the safe and stable operation of the UHVDC transmission system. The actual monitoring system of the flow station is simulated in detail. The system uses the simulation method of "simulation" to realize the OWS simulation of the converter station by the man-machine interface dynamic simulation technology, and carries out the actual system from the window style, the monitoring function and the control function. Monitoring simulation system is exactly the same in man-machine interface, operation menu, latching logic, DC alarm & display and other functions as the actual system.



(1)

(2)

Figure 7. OWS Simulation of converter station

The main simulation functions of monitoring system include sequence operation, AC/DC field monitoring, communication field monitoring, valve group monitoring, valve group water cooling system monitoring and station power supply system monitoring, etc. All these interfaces provide the operation and monitoring of a variety of equipment, sequence operation, AC/DC remote control and rheological tap remote operation.

## VI. Demonstration System

Based on the above researched methods, the simulation training system of Jinping-Suzhou ± 800kV DC transmission project was developed. The system realizes the mechanism modeling, 3D scene modeling and panoramic simulation of the equipment and operation monitoring of Jinping- Suzhou converter stations.

### A. *Interface Effect*

Fig. 7 (1) is the DC field sequential control flow chart, (2) is the DC field main wiring diagram. Fig. 8 (1) is the converter station primary equipment three-dimensional scene, (2) is the converter station secondary equipment three-dimensional scene.


(1)

(2)

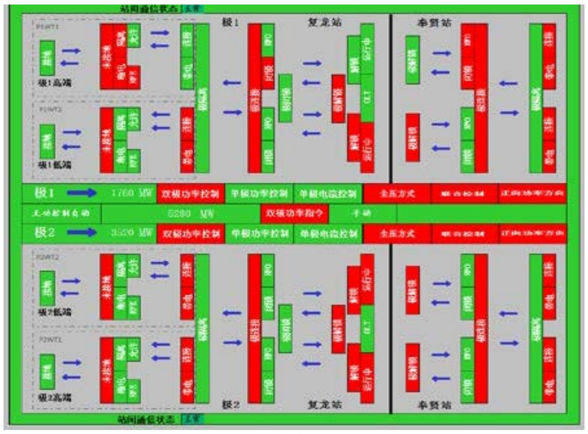
Figure 8. Three - dimensional simulation scene of converter station

### B. *Training Function*

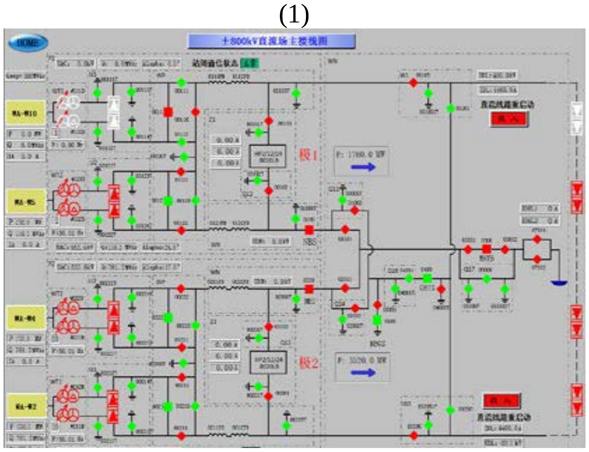
This section analyzes the simulation function of UHVDC converter station with short fault of pole 1 high valve group in Jinping converter station. Under normal conditions, the converter station in the bipolar double valve is full loaded, with ± 800kV full pressure operation and the transmission power of 6,400MW, as shown in Fig. 7 before the failure.

When the pole 1 high valve short-circuit fault occurs, the pole 1 high valve short-circuit protection action, high valve is blocked, and the corresponding converter transformer's AC switches are tripped and blocked.

DC high valve bypass switch 8011 and bypass isolator 80116 are closed, high valve anode isolator 80111, cathode isolator 80112 are opened, the voltage of pole 1 steps down to 400 kV, carrying on 1 750 MW. The state after the failure is as shown in Fig. 9. The simulation results, fault action process and fault information results are exactly the same as the actual system; the primary equipment and the second equipment 3D scene changes are correct according to system failure logic.



(1)



(2)

Figure 9. Screen after the fault

## VII. THE END

The all-digital UHVDC transmission simulation training system truly reproduces the OWS system of the converter station and the three-dimensional scene of the primary equipment and secondary equipment, and realizes the simulation of the AC/DC hybrid power grid and the DC control protection system, which provides the operator with Special training environment for monitoring, operation, inspection and accident handling of UHVDC converter stations. Flexible deployment of the system at the same time to meet the exchange station in situ training and training center focused on training needs for the training of the converter station has brought great convenience.

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