Research on the Method of Safe Operation and Maintenance for UHV Equipment

Ying Pei 1, *, Lin Niu 1, Xinghua Liu 2, Shitao Wang 1, Yan Zhang 1, Lei Wang 1, Yanyan Zhang 1 and Haifeng Li 1

1 State Grid of China Technology College, Jinan, China
2 State Grid Zibo Power Supply Company, Zibo, China

*Corresponding author e-mail: peiyingee@163.com

Abstract. With the continuous operation of UHV projects, the problem of safe operation and maintenance of UHV power grids has become an urgent problem to be solved. UHV main equipment has the characteristics of large volume, complicated structure, high technical content, and difficult operation and maintenance, and the scope of equipment failure is relatively large. This paper has made an in-depth analysis of the UHV substations and converter stations that have been put into operation, systematically studied the safety problems that need to be solved urgently, and finally, given a new method for the safe operation and maintenance of UHV equipment. The method has been applied to the maintenance of UHV substation equipment, and the results have proved the effectiveness, practicability and completeness of the new method.

1. Research Background and Purpose

China has a vast territory and its energy resources are distributed unbalanced extremely across the regions. More than 70% of coal resources are distributed in North and Northwest China. 80% of China's water resources are distributed in southwest regions, such as Sichuan, Yunnan, Guizhou, and Tibet. Wind resources are mainly distributed in northeast, north and northwest China. Solar energy resources are mainly distributed in the Qinghai-Tibet Plateau, Gansu, Ningxia, southern Xinjiang, and Inner Mongolia. However, more than 70% of China's load demand comes from the eastern and central regions, and the large clean energy bases in the west are 1,000 to 3,000 km away from the load centers in the east. From the above analysis, it can be seen that there are a large number of clean energy sources in the western and northern regions, but the local consumption space is limited, and the situation of abandoning water, wind and light is severe. There is a large demand for electricity in the central and eastern regions, and it is impossible to build power points on a large scale. Therefore, the development of UHV is a radical solution to the deep-seated contradictions between energy problems and power development. It is an urgent need to meet the large-scale development of various large-scale energy bases and new energy sources. It is also the only way to promote the energy conservation and the sustainability of China's energy industry.

In January 2009, Changzhi-Nanyang-Jingmen 1000kV UHV AC test demonstration project was put into operation. In July 2010, the Xiangjiaba-Shanghai ± 800kV UHV DC transmission demonstration project was put into service. The safe and stable operation of UHV AC and DC demonstration projects have fully verified the technical feasibility, system safety, equipment reliability and environmental
friendliness of UHV power transmission. At the end of 2019, China has 8 UHV AC projects and 13 UHV DC projects have been completed and put into operation.

With the continuous operation of UHV projects, the safety operation and maintenance of UHV power grids have become an urgent problem. UHV equipment is bulky, complex in structure, high in technical content, difficult to operate and maintain, and has a large range of equipment failures. Therefore, higher technical requirements are required for the staff engaged in the UHV equipment operation and maintenance. In view of the current mismatch situation between the skill level of the employees working in UHV and the demands of the post, the training program for UHV transmission has been researched systematically, and developed the corresponding training course system, to strengthen UHV transmission operation and maintenance personnel training, and to provide personnel guarantee for the safe and stable operation of the UHV grid.

2. Research Content and Method
In order to make the training program for UHV transmission operation and maintenance to be scientific, practical, and complete, this paper analyzed the training need firstly, and then studied the training program, finally, the textbooks, courseware, work instructions, and problem sets were developed. The research was carried out in sequence, of which, training need analysis is the foundation, and the training program research is the key.

2.1. Need Analysis
Training need analysis is the first step in the entire process of training activities, and is the basis for formulating training plans, designing training programs, implementing training activities, and evaluating training effects. This paper uses a combination of document interpretation and investigation to analyze the training needs of UHV personnel. On the one hand, by reviewing the post competency standards, the post competency requirements of UHV operation and maintenance professional and technical personnel are clarified. On the other hand, go deep into the UHV substation, and investigate and analyze the current status of the relevant personnel's job capacity. By comparing and analyzing the post competency requirements with the actual status of the post competency, the training need of UHV operation and maintenance personnel are summarized.

2.2. Researching on Program
The training program is a programmatic document during the implementation of the training. It controls all aspects of the entire training process, and is a powerful guarantee for the effectiveness of the training. Based on the analysis of training need, fully considering the diversity of training objects, the completeness of training content, the diversity of training forms, and the rationality of assessment method, a program suitable for the training of UHV operation and maintenance staff has been developed. In this training plan, the training objectives, training courses, training methods, training teachers, assessment methods, and other key content have been clarified, and the requirements for the used teaching materials, courseware, and work instructions have been put forward.

2.3. Development of Materials
The training material is a written carrier of the training content, which is professional, practical, standardized, and inherited. During the development of UHV training materials, from the perspective of training and teaching, a series of training materials, covering the basic structure, working principles, operating methods, maintenance methods and advanced technologies of UHV equipment, has been developed.

2.4. Designing Courseware
According to training goals, training outlines, and training contents, the training courseware is made. It has the characteristics of rich content, rigorous logic, novel forms, and is a good way to assist training and teaching. The work of UHV operation and maintenance has the characteristics of high technical
requirements, difficult operation, and difficult to transfer knowledge. In order to improve the training efficiency and achieve better training results, a set of the training courseware has been developed.

2.5. Preparation of Work Instructions
The work instructions provide pre-work preparations, work plans, technical requirements, danger points, and preventive measures to ensure that the work process can be completed safely, correctly, and efficiently. It is a very important operating specification at the working site. In this research, a set of work instructions has been prepared to ensure that the training process is safe, standardized and orderly.

2.6. Designing Problem Set
Students can better master the knowledge and skills they have learned through the exercises in the problem bank. The trainer can choose the exercises in the question bank to test the students' mastery of key content and key knowledge. In the UHV training course system, according to the key points and difficulties in the course content, a set of question bank, covering the core knowledge points and key skills, has been developed, which are scientific, practical, systematic and complete.

3. Research Result
Using the above research methods, the training program for UHV operation and maintenance personnel has been developed systematically, clarifying the training objectives, training content, teaching forms, training hours, and other related content. The training outline is shown in Table 1:

| Serial Number | Training Objective | Training Content | Teaching Form | Training Hours |
|---------------|--------------------|------------------|---------------|----------------|
| 1             | Clarify for safety management rules and regulations, operating rules, maintenance specifications, etc. in UHV substations. | (1) UHV Substation Safety Management  
(2) Interpretation of UHV Substation Operation Regulations  
(3) UHV Substation Maintenance Regulations and Typical Case Analysis | Lecture Discussion Case Study | 16 hours |
| 2             | Understand the primary system wiring mode, system operation mode, and equipment configuration in UHV substations. | (1) UHV AC System Structure and Operation Mode  
(2) UHV DC System Structure and Operation Mode | Lecture Exchange Seminar | 8 hours |
| 3             | Master the basic structure, working principle, operation mode and maintenance method of UHV AC electrical main equipment. | (1) UHV Transformer  
(2) Gas Insulated Switch (GIS)  
(3) Voltage Transformer  
(4) Current Transformer  
(5) Reactor  
(6) Series Compensation Device | Lecture Simulation Learning Practical Training | 24 hours |
| 4             | Master the basic structure, working principle, operation mode and maintenance methods of UHV DC electrical main equipment. | (1) Converter Valve  
(2) Converter Transformer  
(3) DC Field Equipment  
(4) AC Field Equipment | Lecture Simulation Learning Practical Training | 24 hours |
| 5             | Master the equipment configuration, function test, operation maintenance method, etc. of the UHV secondary system | (1) UHV AC Protection System  
(2) UHV DC Control System  
(3) UHV DC Protection System | Lecture Simulation Learning Case Study | 16 hours |
In Table 1, the core knowledge points that need to be mastered as the personnel engaged in UHV transmission operation and maintenance include:

1. UHV Substation Operation and Maintenance Regulations
2. Basic Structure and Working Principle of Electrical Main Equipment in UHV AC Substation
3. Basic Structure and Working Principle of Electrical Main Equipment in UHV Converter Station
4. Basic Theory and Functional Characteristics of UHV Secondary System

In Table 1, the key skills that need to be mastered as the personnel engaged in UHV transmission operation and maintenance include:

1. UHV Substation Operation Mode and Switching Operation.
2. Daily Operation and Maintenance of UHV Electrical Equipment.
3. Maintenance Method of UHV Electrical Main Equipment.
4. Maintenance Method of UHV Control and Protection System.

4. Practical Application

In September 2018, as two new UHV substations were put into operation in Shandong Province, a group of workers were required to take charge of the operation and maintenance of these two substations. About 80 people participated in the training of operation and maintenance class. Among the trainees, about 60% of them were previously engaged in the operation and maintenance of substations with a voltage level of 500kV and below. They have experience in the operation and maintenance of Extra-high-voltage substations, but have no experience in UHV substations. About 40% of the staff are new college students majoring in electrical engineering, and have no working experience. The above research results were applied to the implementation of this training course, the training period was 12 days, and the final exam was conducted on the last day of the training. By participating in this training, the trainees have learned a lot, not only gained the UHV knowledge systematically, but also greatly improved the operation and maintenance skills of UHV equipment. Judging from the results of the final exam, all of the students passed the final exams successfully. The final exam has covered the core knowledge points and key skills, using a combination of written and practical examination.

Acknowledgments

This work was financially supported by Youth Innovation Team Programme of Shandong College (No.2019KJN025).

References

[1] Research and Application of UHV DC Operation and Maintenance Technology System [M], Cheng JianDeng, China Electric Power Press, 2017, P3-8.
[2] ULTRA-HIGH VOLTAGE AC&AC GRID[M], Liu Zhenya, China Electric Power Press, 2013, P7-14.
[3] Intelligent Control System of UHV Converter Station Operation and Maintenance [J], YI Fuquan, Power and Energy, 2019(40), P162-164.
[4] Staff Training Practice Aimed at Improving UHV Operation and Maintenance Capability [J], Cui Wenliang, Guo Kai, Human Resources, 2016, P30-31.
[5] Discussion on Electric Power Talent Development and Training [J], Cheng Liwei, Science and Technology & Innovation, 2017(18).