WEP Warwick Evans Publishing

International Journal of Mechanical and Electrical Engineering

ISSN: 3005-9615 (Print), ISSN: 3005-7132 (Online) | Volume 4, Number 1, Year 2024
DOI: https://doi.org/10.62051/ijmee.v4n1.07
Journal homepage: https://wepub.org/index.php/IJMEE/index

Safety Management of Ultra-high Voltage Substation Equipment Operation

Jinghui Liu [1], Guangze Zhu [2,*], Tuo Xia [1], Zhen Xu [1]

[1] State Grid Zhejiang Electric Power Co., Ltd. Shaoxing Power Supply Company, Shaoxing, China
[2] Zhejiang Electric Transmission and Transformation Engineering Co., Ltd, Hangzhou, China
*Corresponding author: Guangze Zhu (Email: 1109947846@qq.com)

ABSTRACT

Ultra-high voltage substation plays an important role in the modern power system. It is the transmission hub of power, connecting large power plants and end users. With the continuous expansion of power grid scale and the improvement of voltage level, the safety management of ultra-high voltage substation equipment operation is particularly important. Based from the characteristics of ultra-high voltage substation, this paper will systematically study and discuss the key links of equipment operation safety management, in order to provide useful reference for improving the safe and stable operation level of China's power system.

KEYWORDS

Ultra-high Voltage; Substation; Equipment Operation; Safety Management.

1. INTRODUCTION

Figure 1. Ultra-high voltage substation

With the rapid development of power technology and the country's increasing attention to power infrastructure, ultra-high voltage (Ultra tra-High Voltage, UHV) transmission technology has become the core component of modern power system[1-3]. As a hub connecting power generation and users, the equipment operation safety of the uHV substation is undoubtedly directly related to the stability of the power network and the continuity of power supply[4-7]. Ultra-high voltage substation plays an important role in the modern power system[8]. It is the transmission hub of power, connecting large

power plants and end users. With the continuous expansion of power grid scale and the improvement of voltage level, the safety management of ultra-high voltage substation equipment operation is particularly important. Based from the characteristics of ultra-high voltage substation, this paper will systematically study and discuss the key links of equipment operation safety management, in order to provide useful reference for improving the safe and stable operation level of China's power system [9-10].

2. FEATURES AND CHALLENGES OF THE UHV SUBSTATION

As an important facility in the power system, the design, construction and operation of ultra-high voltage substation have the following remarkable characteristics:

System complexity and stability requirements are higher: the voltage level and power transmission capacity involved in the uHV transmission system are far beyond the conventional power grid, and its stability requirement is extremely high. As the node of the system, the substation needs to ensure that it can still be converted reliably under extreme operation conditions.

Large-scale and integrated equipment: In order to meet the transmission needs of high voltage and large capacity, ultra-high voltage substations are usually equipped with large and complex electrical equipment. The improved integration of these devices allows a single failure to trigger a chain reaction that threatens the security of the entire system.

Technology advancement and autonomy: UHV transmission technology involves cutting-edge power electronics technology, control technology and material science and other fields. This means that the design and operation of uHV substations need to rely on highly advanced technology solutions, and to a certain extent, it reflects a country's autonomy in the field of electric power technology.

However, in the actual operation process, the uHV substation still faces a series of severe challenges:

Risk of natural disasters and human factors: natural disasters such as earthquake, flood and typhoon, as well as human factors such as terrorist attack and misoperation may pose a serious threat to the safe and stable operation of uHV substation.

The impact of environment and climate: the operation of ultra-high voltage equipment is greatly affected by environmental conditions and climate factors, such as high temperature, high humidity, pollution and lightning strike and other extreme environments may lead to the decline of equipment performance or failure.

Difficulties of maintenance and overhaul: the maintenance and overhaul of ultra-high voltage equipment not only requires professional skills and tools, but also needs to consider many factors such as safety isolation and power failure cooperation, which not only increases the operation and maintenance cost, but also limits the availability of the system.

Network security threat: With the promotion of smart grid construction, ultra-high voltage substations have been gradually included in the category of informatization and automation. However, this also makes them more vulnerable to the risk of coming from cyber-attacks, posing a new threat to the network security and information security of the power system.

To sum up, the uHV substation plays a vital role in the modern power system. In order to ensure its safe and stable operation, it is necessary to carry out comprehensive management and control from all aspects from planning and design to operation and maintenance, constantly improve the equipment performance and optimize the operation and maintenance mode. Especially in the face of natural disasters, man-made damage, deterioration of environmental and climatic conditions and network security in the process of intelligent development and other issues, we need to strengthen technological innovation and scientific research, improve the resilience and safety of China's power

system, to provide a strong guarantee for the sustainable and healthy development of the economy and society.

3. OVERVIEW OF OPERATION SAFETY MANAGEMENT OF UV SUBSTATION EQUIPMENT

The safety management of equipment operation of ultra-high voltage substation refers to ensuring the safety, stability and reliability of substation equipment under high voltage operation through a series of organization, system, technology, operation and supervision measures. Safety management not only involves the daily maintenance and overhaul of equipment, but also includes the establishment and implementation of preventive safety management strategies.

3.1. Organizational Structure and Management Process

First of all, a clear safety management committee should be set up in the organizational structure of the UHV substation, which is responsible for the formulation and implementation of safety rules and regulations, emergency plans and training plans. At the same time, it is necessary to build a complete set of perfect safety management process system, covering the whole life cycle from equipment acceptance, installation and debugging to operation inspection, fault handling, scrapping and update.

3.2. System Construction and Standard Norms

It is very important to establish a sound equipment operation safety management system, which should cover the key fields such as operation ticket implementation, accident emergency handling and maintenance operation permit. At the same time, it should be compiled according to the safety standards and regulations of relevant equipment at home and abroad, and continuously improved according to the relevant regulations and actual operation experience of state Grid Corporation.

3.3. Risk Assessment and Hidden Danger Management

Equipment risk assessment is an important means to identify equipment safety risks. Through the comprehensive analysis and evaluation of the operating conditions, historical fault data, environmental impact and other aspects of the equipment, the potential risk points and danger degree can be obtained, which provides a basis for making a scientific and reasonable maintenance and overhaul plan..

3.4. Personnel Training and Qualification Certification

The technical ability and safety awareness of the operators are one of the key factors to determine the safe operation of the substation. Therefore, it is necessary to regularly organize the operation and maintenance personnel to conduct professional knowledge training, skill assessment and safety procedures training to ensure the overall quality and ability level of the operation and maintenance team.

3.5. Technical Support and System Support

With the continuous development and application of intelligent technology, the use of advanced monitoring and diagnosis tools, intelligent security system, fault warning platform and other means can effectively improve the monitoring and management level of equipment and emergency response efficiency. In addition, the intelligent support system such as remote expert diagnosis system and operation and maintenance auxiliary decision-making system can provide convenient and efficient

operation guidance and technical support for the power grid dispatching and operation and maintenance personnel.

4. IMPLEMENTATION STRATEGY OF OPERATION SAFETY MANAGEMENT OF ULTRA-HIGH VOLTAGE SUBSTATION EQUIPMENT

Equipment inspection is an effective measure to find out equipment defects and abnormal conditions in time, especially in the key power transmission node such as ultra-high voltage substation, the importance of inspection work is self-evident.

First of all, scientific and reasonable inspection plans and procedures should be formulated, and the inspection items, cycles, standards and responsible persons of the equipment should be defined. Check the appearance, sound and smell of the high-voltage electrical equipment in detail, and record the change trend of the key parameters such as the operating temperature and pressure of the equipment. Regular inspection helps the operation and maintenance personnel to timely understand the operation status of the equipment and its development trend.

In addition, the use of advanced sensors and monitoring equipment for real-time monitoring of key parts, can realize the continuous tracking and analysis of the equipment status, such as transformer temperature field monitoring, mechanical characteristic measurement of circuit breakers, etc., so as to more accurately grasp the operating status of the equipment and identify potential faults or failure modes in advance.

When abnormal signals are found through inspection and monitoring, the operation and maintenance personnel shall respond quickly according to the emergency plan, judge the possible cause of the failure and immediately report to the relevant personnel for handling.

In order to ensure the quality and effect of the inspection and monitoring work, the implementation should also be assessed and rewarded, so as to improve the enthusiasm and responsibility of the operation and maintenance personnel.

In the future, it is necessary to further improve the inspection and monitoring means, combine the Internet of things technology and the intelligent data analysis technology, and improve the intelligent management level of the equipment, so as to escort the safe and stable operation of the power system.

Figure 2. Ultra-high voltage equipment maintenance

Also, improve the emergency handling and accident response capabilities is very important to formulate emergency plans and conduct drills for possible emergencies. When the failure is inevitable,

reasonable disposal measures must be taken to minimize the impact and restore normal operation as soon as possible.

Emergency handling and accident response is a systematic work involving multiple links and many departments of cooperation.

First of all, we need to establish and improve the emergency response management system of the power system, and clarify the division of responsibilities at all levels and the requirements of the emergency process and the construction and management of the rescue team.

Secondly, targeted emergency plans should be formulated according to the various emergencies that the UHV substations may be faced with, and regularly revised and improved to make them in line with the latest actual situation.

Organize professional training to improve the emergency response ability of operation and maintenance personnel, including crisis awareness education, on-site handling skills drills, etc.

In daily work, we should conduct a comprehensive risk assessment to identify the potential risk sources and establish the preparation and revision of the corresponding database supply emergency plan.

Strengthen the communication and coordination with meteorological, hydrological, earthquake and other external institutions to share information so as to timely obtain the early warning information of natural disasters and make preventive preparations in advance.

Finally, we should strengthen the supervision, inspection and evaluation of the implementation of the plan, and immediately rectify the problems found, and constantly improve the emergency plan system.

In order to improve the efficiency and effect of emergency treatment, ultra-high voltage substations can also use modern information technology means. For example, the UAV is used to obtain the real-time image data of the accident site and conduct simulation training with VR / AR and other technologies to enhance the operation process of the emergency plan in the virtual environment as close to the real world.

In addition, attention should be paid to strengthening the social linkage mechanism and maintaining close communication with social rescue forces. In case of major emergencies, the emergency response mechanism can be quickly launched to jointly deal with the crisis.

5. FUTURE PROSPECT OF OPERATION SAFETY MANAGEMENT OF ULTRA-HIGH VOLTAGE SUBSTATION EQUIPMENT

5.1. Extensive Application of Intelligent Operation and Maintenance System

Intelligent operation and maintenance system will become the inevitable trend of the development of UHV substation in the future. Such systems have multiple functions, such as real-time monitoring, remote diagnosis and accurate control, and can realize the comprehensive perception and intelligent analysis and diagnosis of the key equipment in the station.

By using big data technology to deeply mine the operation data of the equipment, the key indicators of the equipment life cycle and performance decay trend are predicted. This helps the operation and maintenance personnel to find the potential failure points in advance, and make the corresponding preventive maintenance plan.

With the help of artificial intelligence algorithm to simulate the equipment fault model and its impact, the root cause of the fault can be quickly and accurately found and the optimal solution can be proposed.

In terms of fault diagnosis, the accuracy and sensitivity of equipment internal state monitoring can be improved by using advanced technologies such as voice print recognition and image analysis.

At the same time, the Internet of Things technology is used to realize the interconnection between devices to build a unified intelligent operation and maintenance platform, and realize data sharing and collaborative operation to greatly improve the operation and maintenance efficiency and service quality.

5.2. Risk Early Warning and Active Safety Management

In order to further improve the operation and management level of uHV equipment, the capacity construction of risk early warning and active safety management should be strengthened.

By improving the risk management system, establish a scientific and reasonable evaluation index system, and classify and classify the risk management.

Use big data to analyze the operation status of the power system and the change of the influencing factors in real time to warn the operation and maintenance personnel to take corresponding preventive measures in advance.

At the same time, strengthen the safety protection design and development of intelligent fault diagnosis and prediction and early warning technology to achieve early detection and early treatment of hidden equipment.

Carry out equipment condition maintenance (CBM) by monitoring the real-time data of the equipment to determine the existence of potential faults and carry out maintenance in advance to avoid affecting the normal production operation.

In addition, we should actively explore the application of blockchain and other technical means to ensure the authenticity and imtamability of security management information, enhance the credibility and transparency of management, and promote the trust and cooperation among the relevant parties to jointly build a safe and reliable power transmission network.

5.3. Innovation and Reform of the Operation and Maintenance Mode

Facing the new challenges of intelligent substation, the traditional operation and maintenance mode has been difficult to meet the new requirements.

In the future, the operation and maintenance mode will shift from manual to the mode of less people on duty and even no duty. With the help of intelligent robots, inspection, operation and daily maintenance will reduce labor costs and improve work efficiency.

The Internet of Things, cloud computing and other technologies to build a remote intelligent monitoring platform to realize the centralized monitoring and management of multiple substations to improve the management efficiency.

At the same time, strengthen the construction of the operation and maintenance team to cultivate the operation and maintenance team with a high sense of responsibility, exquisite technology and innovative spirit to provide them with the necessary career development channels and incentive mechanism to improve the overall operation and maintenance level.

In addition, attention should also be paid to cultivating the knowledge structure of operation and maintenance personnel, such as virtual reality and artificial intelligence, to meet the needs of the future power operation and maintenance market and contribute more to the sustainable development of the power industry.

6. SUMMARY

As a hub connecting large energy base and load center, ultra-high voltage substation plays an irreplaceable role in the process of building a safe, efficient, clean and low-carbon modern energy system. The safety of its equipment operation is crucial to ensuring the safe and stable operation of the power grid system.

The safety management of ultra-high voltage substation is a systematic project that requires us to work hard for a long time. Looking forward to the future, we have reason to believe that under the joint efforts of the power industry, we can further strengthen the safety management of equipment operation and contribute more to building a clean, low-carbon, safe and efficient modern energy system to promote the sustainable and healthy development of the power industry to help realize the beautiful vision of harmonious coexistence between man and nature.

In short, the safety management of ultra-high voltage substation equipment operation is not only an important long-term task, but also a frontier full of challenges and opportunities. The field of science and technology deserves our in-depth study, active exploration and continuous progress. In the future work, we will continue to carry forward the spirit of nail, devote ourselves to the power industry with more enthusiasm, and strive to ensure the safe and stable operation of the ultra-high voltage power grid, and contribute wisdom and strength to the realization of the realization of "carbon peak" and "carbon neutral" goals! Let us work together and forge ahead to create a new and brilliant chapter on the road of ensuring national energy security and promoting sustainable and healthy social and economic development.

REFERENCES

[1] Qiao Qingqing, Zhao Xiaoli. Research on the design and implementation of substation operation and maintenance monitoring system [C] / / China Electric Power Equipment Management Association. Collection of national Green Digital Intelligent Power Equipment Technology Innovation Achievements Exhibition (I). State Grid Ningxia Yinchuan Power Supply Company; 2024:3. DOI: 10.26914/c.cnkihy.2024.022677.

[2] He waves, Gao Asia. Analysis of the operation and maintenance technology of smart substation [J]. Integrated circuit applications,2021,38(12): 202-203. DOI: 10.19339/j.issn.1674-2583.2021.12.092.

[3] Huang Jian, Jiang Qiyun. Troubleshooting and safety management analysis of substation operation [J]. Henan Science and Technology,2020,39(31):144-146.

[4] Feng Zhibin. Safety analysis of power system substation operation [J]. Technology wind,2020, (03):171. DOI: 10. 19392/j.cnki.1671-7341.202003144.

[5] Hou Wei. Safe operation management and equipment Maintenance of the substation [J]. Digital communication world, 2019, (12):230-231.

[6] Wang Shanyuan, Wang Hongzhe, Li Dianyang, et al. Equipment-centered "integrated" management system for monitoring information [J]. Science and Technology information in China, 2019, (20):66-68.

[7] Zhang Liying. Safety management and equipment maintenance of power system [J]. China Equipment Engineering, 2019, (19):63-65.

[8] Zhou Yuanlong. Safe operation management and equipment Maintenance of the substation [J]. Communication world,2019,26(08):315-316.

[9] Power administration. Thoughts on the standardization construction of safe operation management of substation equipment [J]. Yunnan Chemical Industry,2018,45(04):223.

[10] Huang Jingjing. Discussion on safety management and equipment maintenance of power system [J]. Digital design,2018,7(01): 111-112. DOI: 10.19551/j.cnki.issn1672-9129.2018.01.044.