

# Safety Management and Risk Control Strategy of High Voltage Power Line Installation and Construction

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**Abstract:** High voltage power line installation construction, safety management and risk control are the main premise to ensure the smooth progress of the project and personnel safety. In recent years, with the rapid development of the power system, the construction scale of high-voltage power lines is getting larger and larger, and the complexity and technical difficulty are gradually increasing. Therefore, how to carry out effective safety management and risk control has become an important link that cannot be ignored in the construction process. This paper focuses on the safety management and risk control strategy of high-voltage power line construction, with the purpose of formulating scientific and reasonable management strategy for power construction enterprises, so as to reduce the hidden dangers in construction and improve the quality and efficiency of the project. This paper first expounds the importance of construction safety management of high voltage power lines, discusses the industry safety standards, and analyzes the situation of safety management at home and abroad. Based on this, this paper makes an in-depth analysis of construction risks, uses appropriate methods to identify risks, and discusses common risk types and influencing factors. A series of safety management measures such as safety training for construction personnel, the use of advanced safety equipment and technology, and the establishment of strict safety supervision and assessment mechanisms are put forward to ensure the safety of personnel and equipment during construction. Finally, it puts forward specific risk control strategies, including risk control principles, specific implementation measures, preparation and

implementation of risk emergency plans, in order to strengthen safety management during construction and minimize accidents. At the same time, it is emphasized that in the construction process of high-voltage power line construction, construction enterprises should adjust and improve their safety and risk management strategies according to the specific conditions of the project and construction environment. Through the detailed analysis and discussion of the above content, it is expected to provide some theoretical support and practical guidance for the construction of high-voltage power lines in the future.

**Keywords:** High Voltage Power Line; Safety Management; Risk Control; Construction Risk; Safety Measures

## 1. High Voltage Power Line Installation Construction Safety Management Overview

### 1.1 The Importance of Security Management

The safety management of high voltage power line assembly project plays an indispensable role in maintaining the personal safety of construction personnel, ensuring the quality of the project and reducing the risk. In the implementation process of power engineering, especially in the construction and management of high-voltage power cables, there are multiple challenges such as complicated construction scenarios, high-risk air operation, and the installation and calibration of power devices. Therefore, it is essential to establish a comprehensive safety management mechanism and fine supervision of each construction process.

The technical complexity and potential hazards faced by high-voltage power lines during the

laying process highlight the indispensable role of safety management. Due to the high voltage, high current and high altitude working environment during construction, even the smallest operational error can cause extremely dangerous accidents. In the past five years [1,2], among the injuries suffered by construction workers in the power field, 21 percent of the incidents occurred in the high-voltage power line laying stage, and the root cause can be traced to the lack and omission of safety control strategies.

Security control is an indispensable key support for enhancing the overall effectiveness of the project [3]. The construction of high-voltage power lines often needs to invest huge human, material and financial resources. If accidental accidents occur, in addition to direct financial losses, they may also lead to complex legal disputes and damage the reputation of enterprises, which will lead to more far-reaching indirect economic costs. Therefore, strengthening safety management measures can significantly reduce the frequency of safety accidents, ensure the smooth construction process and project quality, and then comprehensively improve the overall efficiency of the project.

Second, ensuring safety governance is essential to the professional well-being of the construction team and the social obligations of the company. As a high-risk area of power construction, it is important to ensure the occupational health and safety environment of construction workers. Through the implementation of systematic safety management strategies, enterprises can not only ensure the life safety of construction team members, but also enhance the job satisfaction of employees and enhance the centripetal force of enterprises. With the increase of social expectations for enterprises to assume social responsibility, excellent safety management has become a key means for enterprises to practice social responsibility and build a positive corporate image.

In order to ensure the effective implementation of safety management measures during the construction of high-voltage power lines, the construction team must establish a sound safety management system, clarify the responsibilities of each post, prepare detailed safety production operating procedures, and regularly carry out safety training and practical

exercise. Modern safety management should efficiently integrate information technology means, build a safety information processing platform, in order to achieve real-time monitoring and information analysis of the construction site, and then enhance the scientific and practical effectiveness of safety management.

To sum up, the safety management of the installation and construction of high-voltage power lines is crucial, and its value is mainly reflected in ensuring the safety of the construction process, enhancing the economic benefits of the project, practicing corporate social responsibility, and promoting the continuous prosperity and progress of the power industry. Construction contractors and leaders should continue to optimize and innovate safety management mechanisms to cope with increasingly complex work scenarios and social changes.

## 1.2 Safety Standards Within the Industry

The safety control of the construction of high-voltage power line installations is a core element to ensure the smooth and safe execution of power projects. A variety of procedures and guidelines have been developed in this area with the aim of reducing construction risks and enhancing project quality [4].

At the national and industry level, a set of fundamental safety norms has been established to ensure the safe implementation of high-voltage power line laying operations. In accordance with the relevant provisions of the "Electric Power Safety Work Regulations" and the "Electric Power Construction Quality Acceptance Code" (GB50202-2002), the contractor shall uncompromisingly comply with the established specifications when performing the laying and calibration operations of high-voltage power lines. These guidelines provide a comprehensive system of guidelines for project planning, team layout, site risk management, and completion review to ensure that the construction process meets regulatory requirements and ensures the safety of the operating environment.

In addition [5] to national regulations, industries have also established a set of special safety guidelines to guide safety practices in the laying and construction phases of high-voltage power lines in more detail. For

example, the "Green Construction Management Code for Electric Power Enterprises", promulgated by the National Federation of Electric Power Companies of the People's Republic of China, requires construction contractors to strengthen process management and improve construction plans in order to reduce environmental damage and resource consumption. The State Grid Corporation of China also issued the Implementation Rules for the Safety Management of Power Engineering Construction Projects, which clarified the safety control norms and implementation processes of the work site.

From the national level to the professional field, the construction of detailed safety norms for the construction and construction of high-voltage power lines has established a clear direction. By following these codes, construction companies can reduce accidents, improve the quality of construction, and ensure the smooth development of projects. These security specifications not only constitute the basic architecture of the industry, but are constantly evolving and upgrading. With the growth of technology and experience, the demand for safety specifications in the industry continues to rise to effectively address the evolving safety challenges faced by power engineering projects.

### **1.3 Current Situation of Safety Management at Home and Abroad**

When analyzing the safety management challenges in the construction of high-voltage power lines, it is particularly important to explore the current situation at home and abroad. In view of the rising global demand for electricity, the laying and construction tasks of high-voltage power lines have increased significantly, which highlights the importance of construction safety governance and has become a focus area that needs to be further explored. The situation of construction safety management of high voltage power lines at home and abroad shows certain heterogeneity, which is mainly due to the difference of legal norms, technical strength and management mechanism in each region.

In China, recently, the level of attention to the safety management of China's power engineering construction has increased significantly. The large state-owned enterprises

represented by the State Grid have integrated many international leading safety production norms, such as the adoption of OHSAS18001 occupational health and safety management system standards, aimed at strengthening the safety management and risk control of construction sites. Based on 2023 data, the frequency of accidents in the construction of high-voltage power lines has decreased significantly by about 15 percent after the implementation of more rigorous risk assessment procedures. China continues to promote the implementation of innovative means such as building information modeling (BIM) technology and drone inspection in the field of safety management, which has significantly improved the safety management level of construction projects.

In this context, the Chinese authorities continue to optimize the supporting laws and regulations. Recently, the implementation of norms such as the "Safety Production Law" and the "Regulations on the Supervision and Management of Power Production Safety" has forced power construction units to strictly implement and execute all safety control instructions. 98.7 percent.

From a global perspective, the safety management strategies of different countries are unique, given the differences in the foundation of their power systems, technological environment and regulatory framework. Taking Europe as an example, EU member states have widely adopted international electrical safety norms such as IEC61140 and built a comprehensive power engineering safety governance framework. In 2022, the EU member States have widely implemented risk management strategies in the field of high-voltage power engineering, resulting in a significant reduction in the frequency of accidents, accounting for less than two percent of the total number of construction times, and the probability of safety accidents has been reduced by about 30 percent compared to the past decade. Several European countries have adopted virtual reality (VR) technology for construction safety education, which has effectively enhanced the safety awareness and expertise of workers.

In the United States, the Occupational Safety and Health Administration (OSHA) has established strict occupational safety codes, especially for the entire process of high-

voltage power line engineering, including detailed regulations on the control measures for high-altitude work. 99.5 percent. The United States attaches great importance to the application of intelligent safety management system in the construction of high-voltage power lines, which significantly reduces the probability of safety accidents in the construction process by virtue of real-time monitoring and alarm functions.

It is worth noting that in recent years, Australia's development in the field of high-voltage power engineering safety control is also quite prominent. Australia has introduced an innovative "multiple barriers" risk assessment architecture that focuses on managing the full spectrum of security threats, including technical challenges and human error. 1.5 Through this measure, the economic losses and casualties caused by security accidents have been significantly reduced.

Both domestic and foreign countries have demonstrated their unique strategies and practices in the safety management during the construction of high-voltage power lines. Despite the differences in the background environment, all countries have achieved unity in the core pursuit of safety management, aiming to significantly reduce the accident rate and thus improve the overall efficiency of safety management. In the future, China should absorb more successful strategies from international leading practices, rely on the support of the legal system and technological progress, and continue to optimize the safety management norms for the construction of high-voltage power lines, so as to more effectively deal with the construction safety problems.

## **2. Risk Analysis in High Voltage Power Line Construction**

### **2.1 Risk Identification Method**

In the construction stage of high voltage power lines, risk identification [6] is the basic key to ensure the safety management and risk management of engineering projects. In order to achieve effective risk management and control, multiple risk identification strategies should be integrated. One popular technique is the brainstorming technique. By bringing together project related experts, construction team members and safety management

professionals to analyze and list the potential risks of construction activities. This strategy inspires innovative ideas, encourages participants to articulate diverse perspectives and attitudes, and ensures that a wide range of risks are considered. However, brainstorming has its limitations, mainly due to the significant dependence on the background and skills of the participants, and the identification results are susceptible to personal biases.

One commonly used strategy is failure Mode and Effects Analysis (FMEA). This technology is designed to identify potential failure modes and expected consequences at each construction stage to determine which elements are most critical to the overall safety of the project. The FMEA method uses a structured and systematic method to identify the risk elements that are often missed in the project, so as to implement more accurate prevention and management strategies. FMEA also provides the basis for subsequent risk rating and resource allocation.

The review of historical data is also a crucial part of the risk identification process. By summarizing the accidents and challenges in similar engineering cases in the past, and evaluating them quantitatively, we can extract the common risk sources and their occurrence probabilities and causes. According to the statistics released by the State Grid Corporation, in the construction process, damage to power facilities and falling from heights accounted for 45% of all safety accidents. Therefore, analyzing the past data can not only improve the efficiency of risk identification, but also provide data evidence to make the identification results more credible. The Delphi method is an efficient strategy for gathering the insights of multiple experts on a particular transaction through multiple rounds of anonymous questionnaires and implementing feedback to identify risks. Its advantage is that it eliminates the subjective tendency of a single authority and has high stability and credibility for the risk assessment of specific complex issues. In the construction of high-voltage power lines, the Delphi method can more accurately identify the risks at the technical content level, such as the technical challenges and safety concerns hidden in a particular construction method.

Finally, the field observation method is also a key risk identification tool. Through the

immediate monitoring and recording of the construction site in person, potential safety hazards and their evolution can be quickly identified and tracked. This strategy is particularly useful for identifying immediate and situational risks that are difficult to detect in other ways, such as the effects of climate change on construction sites. Field observation technology can be used in conjunction with various identification methods to generate a more comprehensive and dynamic risk identification perspective. In summary, the implementation of the above technologies can comprehensively and deeply identify various risks in the process of high voltage transmission engineering, and lay a solid foundation for risk evaluation and management.

## 2.2 Common Risk Types

The typical risk types encountered in the construction stage of high voltage power lines include physical risk, environmental risk, technical risk and human risk. Physical risks mainly cover the geological conditions of the construction site, meteorological variability and the safety performance of construction machinery. [7] pointed out in his study that in the process of power line construction, geological instability may lead to construction delays, which will have a significant impact on the construction schedule and economic cost. Therefore, construction contractors should conduct thorough geological surveys to reduce the risk of foundation instability.

Environmental risks mainly cover issues such as climate variability and pollution issues encountered during construction. The unpredictability of the climate poses a significant problem in the construction of power lines, and abnormal weather conditions, such as hurricanes and downpours, can lead to the potential risk of damage to construction equipment and the safety of workers. According to "Standardized Safety Management and Risk Prevention Tactics for Power Engineering Construction" (Wei Minglei et al.,2024), about 27% of power engineering construction projects in South China have encountered various extreme weather disturbances. Therefore, the introduction of meteorological risk assessment system can timely revise the construction scheme and strengthen the environmental strain capacity of the construction site.

The technical risk [8] is closely related to the improper application of technology and the imperfect technical specification in the construction process. In the process of high voltage power line construction, if the immature or unproven technology is applied, it may lead to major problems such as line function failure and leakage. (2024) pointed out that due to the delayed upgrading of technical facilities, the rate of construction failure caused by widespread technical errors reached 15%. In order to prevent technical risks, the practicability and reliability of technical strategies should be ensured.

The human risk mainly comes from the construction personnel's irregular behavior and wrong judgment when executing the operation, which is usually attributed to the lack of safety cognition of the construction personnel or the decision-making error of the management level. According to relevant studies, about 35% of the safety accidents in the construction of the integrated pipe corridor in W City can be attributed to the operation errors of the staff. Therefore, it is crucial to strengthen the training of construction personnel and enhance the decision power of management in risk management.

The common risk categories in the construction of high voltage power lines include physical risk, environmental risk, technical risk and human risk. The building contractor shall thoroughly identify and assess such risks and formulate appropriate treatment plans to ensure the smooth construction process and the safety of construction personnel.

## 2.3 Influencing Factors of Risk

In the construction stage of high voltage power line, the occurrence and influence of risk are the products of interweaving of many factors [9], which can directly affect the construction safety, but also indirectly affect the final quality and reliability of the project. Therefore, detailed analysis of these factors is the cornerstone of risk management.

Climate condition is an important variable that restricts the safety of high voltage power line engineering. Construction projects are often executed outdoors, and climatic factors such as wind, precipitation, and temperature fluctuations are crucial to ensure construction safety. For example, strong winds can cause

instability in construction equipment, increasing the probability of a fall or collision accident. Rainfall can not only cause wet roads, but also may trigger geological disasters such as landslides or debris flows, posing a threat to the life safety of construction workers. According to the data of the China Meteorological Administration, construction safety accidents caused by meteorological factors account for about 20 percent of all accident cases.

Geology is another key constraint. The geological environment of the construction site, including the stability of the horizon and the soil variety, will have a long-term effect on the safety of the project. The uncertainty of the geological condition may trigger foundation instability during the construction phase, thus increasing the risk of the toppling of the tower. Especially in the mountains with complex geological structure, the construction complexity and risk are obviously increased due to the possibility of geological landslide, debris flow and other disasters. The management of such geological risks needs to rely on detailed geological exploration in the early stage and scientific and reasonable planning strategies.

Construction equipment and technical ability is one of the important considerations that restrict construction safety. High-end construction equipment and technology can not only improve construction efficiency, but also effectively reduce safety concerns during construction. However, equipment obsolescence, mechanical problems, improper technical execution and other factors can be derived into construction risks. According to industry regulations, the failure frequency of construction equipment should be limited to 3%, ensuring the smooth operation of machinery and following established procedures is essential.

The professional level and safety awareness of the construction team are crucial to the safety of the construction process. Personnel's technical level, management efficiency, safety cognition, crisis coping skills, etc., are potential drivers of risks. It is often difficult for untrained personnel to take appropriate action in the face of emergencies on construction sites, which may lead to safety risks. According to the data of the State Grid Corporation, more than 60% of construction safety accidents are

caused by improper operation of personnel. Policy criteria and governance structure are important constraints to the safe construction of HV transmission lines. The absence or vague formulation of policy guidelines may drive construction institutions to ignore safety standards during the rush process, which will lead to hidden dangers. Therefore, in the construction phase, the safety standards and laws and regulations issued by the state must be strictly followed to reduce the risk caused by the incomplete management system. The implementation of a rigorous risk assessment and monitoring mechanism can identify potential problems before construction starts and establish appropriate management tactics. Finally, environmental ecological factors should be paid attention to. Some high-voltage power lines pass through ecologically fragile areas, and should pay great attention to the impact on the natural environment during construction to avoid potential environmental pollution caused by engineering hazards. At present, one of the core issues that needs urgent attention is how to reasonably plan and implement the construction of high-voltage power lines while ensuring the ecological environment safety. According to the assessment of the Environmental Protection Agency, the environmental problems caused by construction activities account for about 15% of all major incidents each year.

The risk triggering factors in the construction process of high-voltage power lines are complicated, and should be comprehensively considered and evaluated from multiple dimensions such as climate conditions, ground attributes, equipment performance, human qualifications, laws and regulations, and environmental ecology. With a sound risk identification and control mechanism, construction risks can be significantly reduced to ensure the safety of construction activities and project quality.

### **3. Safety Management Measures for Installation and Construction of High Voltage Power Lines**

#### **3.1 Safety Training for Construction Personnel**

Safety education of construction personnel is one of the key components to ensure the effective realization of safety management

level of high-voltage power line laying engineering. The construction environment of high-voltage power lines is changeable, and the operational risks are significant. If the construction team is not fully prepared in terms of professional skills and safety cognition, the probability of accidents will be highly increased. Based on the perspective of management, strengthening the safety education of construction personnel is the key strategy to improve the safety production efficiency.

Safety training should include basic theoretical education. The construction team needs to have a deep understanding of the operating principles of the power system, be proficient in the characteristics of high-voltage electrical equipment and the safety risks associated with it, and apply the corresponding construction codes and safety guidelines skillfully. In accordance with the provisions of the "Electrical Safety Work Regulations" (GB26859-2011), when performing high-voltage tasks, project members need to have a deep understanding of voltage levels, current characteristics and possible hazards, and ensure that the rules are followed during operation to avoid accidents caused by improper operation.

The construction team [10] should receive centralized practical operation guidance and training. With the help of simulation practice and on-site operation training, the construction team can more intuitively grasp the complex state of the site and hidden dangers. According to statistics, after the implementation of systematic operational training, the frequency of accidents on the site has been significantly reduced by about 30 percent. In the training session, specific situations should be constructed, such as equipment lifting, line laying, and sudden power failure treatment, to simulate the actual working environment, aiming to enhance the coping strategies of the construction team.

Third, the curriculum content of safety education must be continuously updated to respond to the progress of emerging construction technologies and safety norms. Recently, with the popularization of smart devices and technologies, the means of construction of high-voltage power lines continue to evolve, and traditional safety education has been difficult to fully cover

emerging safety challenges. Therefore, the periodic revision of safety training courses to incorporate new construction techniques, equipment operation procedures, and supporting safety risk management strategies is a key way to strengthen the professional competence of the construction team. For example, a risk prediction system built with machine learning algorithms can significantly enhance the accuracy of accident prediction, thus requiring the construction team to conduct necessary system operation training.

Fourth, emphasize the importance of cultivating safety culture and enhancing safety awareness. According to data from the State Grid Corporation, from 2015 to 2020, after comprehensively promoting the construction of a safety culture with full participation, the frequency of safety accidents has been significantly reduced by about a quarter. Enterprises should adopt a variety of means, including education and publicity, periodic seminars and practical experience sharing meetings, so as to enhance the safety awareness and self-protection skills of construction personnel, and ensure that the concept of safety production is widely recognized and practiced.

The psychological well-being of construction workers is also related to their work efficiency and safety. It is found that psychological stress and fatigue are one of the key reasons leading to construction site accidents. Therefore, safety training also needs to integrate mental health guidance, properly plan work hours, and motivate construction workers to participate in psychological counseling to maintain their optimal state of mind to perform tasks.

Ultimately, an evaluation and feedback system to ensure the effectiveness of safety training is critical. With periodic tests and inspections, companies can judge the results of safety education practices and gain insight into how well the construction team understands safety principles. In addition, the feedback mechanism is used to identify the shortcomings and deficiencies in the training process, and timely revise the training program. The safety education of construction personnel is the cornerstone of high voltage power line construction safety, which plays a vital role in preventing safety accidents and optimizing construction process. In the future, construction enterprises should continuously

improve the safety training mechanism to promote the comprehensive progress of construction team skills and safety cognition.

### **3.2 Security Equipment and Technology Applications**

In the process of high voltage power line construction, the implementation of safety devices and technologies plays an important role. The basic measure to ensure the safety of construction workers is to provide high-quality personal protective equipment (PPE). According to the requirements of the Electrical Safety Operation Regulations, field workers should wear personal protective equipment that meets national or professional standards when entering the work area, including but not limited to safety hats, protective gloves, goggles, insulating shoes and fully enclosed safety belts. Such personal protective equipment can effectively prevent falling, electric shock and other potential hazards to ensure the safety of construction workers.

In addition to the use of personal protective equipment, the implementation of advanced monitoring technology can also effectively enhance the level of safety at the construction site. Wireless sensor networks (WSN) and Internet of Things (IoT) technologies have recently been gradually applied in the field of power engineering, becoming the core of advanced solutions. Such technologies enable real-time monitoring of key environmental indicators on construction sites, including temperature, humidity and tremors. With the help of wireless technology, the information is transmitted to the central management platform, and once the detected value exceeds the predetermined warning line, the device will immediately activate the alarm mechanism to ensure that the emergency can be dealt with quickly. In addition, the application of Global Navigation satellite Systems (GNSS) and unmanned aerial Vehicle Systems (UAS) can provide real-time location services on site and monitor workers on high ground to ensure smooth construction activities.

On the other hand, integrated intelligent equipment has become a key strategy to strengthen the safety control of high-voltage power line construction. The robot arm and the automatic construction device assume the role of replacing the human to carry out the high-risk task under some situations that endanger

the personal safety. Robotic arms controlled by remote control and automation can undertake heavy transport tasks and high-altitude support, effectively reducing the possibility of workers facing high-risk environments. Unmanned cranes and excavators can effectively take on tasks that would otherwise be performed by highly skilled workers and significantly reduce the risk of workers being exposed to noise and dust for long periods of time.

In addition to the use of safety devices, efficient information transmission and scheduling mechanisms are also an indispensable part of safety technology in the engineering field. With the help of high-end scheduling software and communication platform, managers can quickly connect with construction teams to ensure smooth information transfer and immediate response. In construction projects, in the face of changes or emergencies, rapid information exchange and decision making can significantly reduce chaos and prevent accidents.

Finally, the comprehensive implementation of safety management system plays an important role in improving the safety control of high-voltage power line construction. These systems integrate many of the above technologies and features to provide comprehensive assistance to security personnel. The security management and control software platform includes project coordination module, inspection supervision module, event processing module, etc., aiming to cover the whole service from risk prediction, engineering planning to instant tracking and on-site control. According to statistical data, the adoption of comprehensive safety management system for construction projects, the probability of accidents can be significantly reduced by about 30%, thereby improving the efficiency and safety of operations.

### **3.3 Safety Supervision and Assessment Mechanism**

In the construction of high-voltage power lines, perfect safety supervision and evaluation system [11] is the key support to maintain construction safety. The safety supervision and assessment mechanism mainly includes the implementation of safety norms, dynamic risk assessment, accident reporting and analysis, and employee safety performance evaluation.



It is essential to ensure that safety practices are followed. In order to ensure the safety of the construction process of high-voltage power lines, enterprises must strictly implement the relevant legal norms and guiding principles issued by the state and the industry, including but not limited to the requirements of the "Electric Power Safety Work Regulations" and the "Electric Power Construction Safety Supervision and Management Measures". The company should establish a special safety regulatory body, whose responsibility is to audit the implementation of safety standards in various construction procedures to ensure that workers perform their tasks in accordance with the established safety guidelines. One statistic reveals that if safety regulations are strictly implemented, the probability of safety accidents can be reduced to 35% of the original.

Dynamic risk assessment is the core component of security management process. The construction site of power engineering is changeable, and various risks may be encountered in the construction process, so it is necessary to implement continuous and flexible risk assessment. With the adoption of risk assessment system and electronic monitoring equipment, possible risks can be detected in time and corresponding prevention strategies can be implemented. For example, the use of drones to patrol routes and real-time monitoring of equipment conditions through the Internet of Things technology can help improve the accuracy of risk assessments.

Third, it is very important to establish and improve accident reporting and investigation mechanism for optimizing safety management system. Build an open accident reporting process to achieve immediate response and accurate identification of the core of the problem after the accident. An accident review team should be formed to analyze each accident in detail, extract the success or failure of the Revelations, and formulate optimization strategies. Based on information published by safety regulators, an optimized accident review process can reduce the probability of recurrence by 40%.

Fourth, employee safety performance evaluation is a key mechanism to promote safety actions. In order to motivate construction workers to pay high attention to safety matters, companies can establish

detailed safety performance evaluation criteria, such as the use of personal protective equipment, records of violations, frequency of participation in safety training, and link such indicators to employee performance bonuses. According to a survey conducted by Shandong Jianzhu University, employees of enterprises implementing performance appraisal system have significantly enhanced their safety awareness, and the reduction rate of safety accidents exceeds 60%.

Enterprises should also implement periodic safety education to enhance the safety awareness and skills of all personnel. During the training process, simulation practices are used to improve the skills of employees to deal with accidents, which is essential to ensure construction safety.

The safety monitoring and evaluation mechanism of high voltage power line construction [12] is a multi-dimensional and all-round structure. A rigorous and efficient supervision system can significantly reduce safety hazards, ensure the life of construction personnel and the smooth progress of engineering operations.

#### **4. Risk Control Strategy in High Voltage Power Line Construction**

##### **4.1 The Principle of Risk Control**

In the construction of high voltage power lines, the risk management and control strategy is the key guide to ensure the safe operation of the construction process [13]. Its core lies in the use of scientific risk assessment and control strategies to minimize the adverse effects of various potential risks during construction activities on personnel safety, project progress and quality, and ecological environment. The basic principles of risk management include the following:

Then there are the universal coverage guidelines. Risk control shall run through the whole process of the construction project, involving the formulation of the construction plan, the selection of equipment, the evaluation of the working environment, the management of the construction team and other aspects. At the early stage of the planning of the construction project, the potential hazardous elements should be comprehensively considered, and advanced technology and protective means should be used to reduce the

risk of accidents and their negative effects. Comprehensive coverage criteria ensure detailed and integrated risk management and control, and build a solid barrier for project safety.

Then there is the principle of systematization. Risk control should be regarded as a comprehensive project, covering pre-risk identification, risk supervision in the process, and impact assessment after the event, and a complete operating system must be built. The study points out that an architecture that integrates risk control throughout the process can effectively enhance the ductility and consistency of risk identification and control. The systematic principle guarantees the scientificity and practicability of the risk control strategy, and provides solid support for the risk management in the construction stage. The third is the dynamic criterion. Risk control shall be dynamically revised with changes in the construction process. [14] Given that the construction environment, weather changes and the uncertainty of the construction process can affect the output of risk assessment, the risk management strategy should show the characteristics of flexible adjustment. Research shows that flexible risk management and control strategies can timely adapt to changes in the construction stage and effectively reduce the frequency of risk occurrence and its negative impact. The dynamic principle ensures the flexibility and adaptability of the risk management and control strategy, and achieves efficient strain support for construction safety.

The fourth point concerns prevention-oriented strategies. In order to effectively manage the potential risks in the construction process, it is recommended to implement the prevention strategy first. This involves the selection of appropriate construction technology, regular safety education, strengthening safety management monitoring and other strategies. Through this study, it is found that the implementation of preventive strategies can significantly reduce the frequency of site safety accidents. The preventive strategy focuses on proactive and forward-looking risk control, which builds a solid foundation for the risk management of construction activities.

The fifth is the economic criterion. Risk management and governance must not only aim to minimize security risks, but also ensure

sustainability and suitability at the economic level. With the help of cost-benefit assessment, the allocation of funds for security protection is precisely planned to ensure that security control strategies are aligned with economic output. The study [15] found that the adoption of economic strategies can not only ensure safety, but also effectively curb the rise of construction costs. The economic principle guarantees the continuity and practicability of risk management and control, and provides fair guidance for the risk management in the construction stage.

Ultimately, the participant principle is involved. The effectiveness of risk control depends on the participation and cooperation of all staff in the construction team. Construction personnel at all levels should clearly define their safety responsibilities, actively invest in risk assessment and control processes, and improve the overall safety awareness and cooperation effectiveness of the construction team through routine safety meetings, communication and response channels. According to this study [16], increasing the frequency of safety interactions and the closeness of cooperation among team members can significantly optimize the effectiveness and outcomes of safety management during construction. The principle of participation ensures full participation and collective cooperation in risk control, and provides all-round support for risk management in the construction stage.

The risk management strategy for the construction of high-voltage power lines not only constitutes a key element of construction safety governance, but also a cornerstone to ensure smooth project progress. In the specific operation stage, the specific operation scenario and project characteristics should be integrated, and various criteria should be flexibly applied to achieve the optimal risk management results.

#### **4.2 Specific Measures for Risk Control**

In the construction of high voltage power lines, the specific strategic planning and execution of risk control is the key support to ensure the smooth progress of the project. Construction enterprises should thoroughly identify potential safety problems at the initial stage of the project, and analyze possible risks in detail with the help of risk assessment methods, such as failure mode and impact analysis (FMEA)

and event tree analysis (ETA), so as to make well-justified decisions for subsequent risk management. According to the 2022 power engineering project safety report (State Grid Chongqing Electric Power Company), more than 70% of construction accidents are not closely related to prior risk assessment, which highlights the importance of strengthening risk identification in the initial stage.

On the other hand, technical approaches play a central role in the field of risk management. Nowadays, a large number of high-voltage power projects have gradually integrated digital and intelligent means. Tools such as drones and laser scanners are used to improve the accuracy of risk monitoring. Specifically, drones can patrol construction sites, collect image data in real time, and use big data processing methods to quickly identify possible safety risks, thereby implementing dynamic monitoring of the site. The use of automated measurement technology can significantly reduce the human measurement deviation, thus ensuring the accuracy and reliability of construction.

On the other hand, building a system is also a crucial link. Construction enterprises should establish sound safety management norms, including clear safety responsibilities, the formulation of operational guidelines, the implementation of regular inspections and assessments. Studies have shown that establishing a clear safety responsibility system can reduce the frequency of accidents on construction sites by about a quarter. Based on this, safety inspections should be carried out periodically to ensure that the construction team can adhere to safety norms. Such testing must be comprehensive and should not be limited to the construction phase, but should also cover important accident-prone steps such as material storage, equipment maintenance and working at heights.

Training and education is the key path to enhance the effectiveness of risk management. According to the safety operation guidelines in the field of power, construction enterprises should implement a comprehensive safety education for their staff at the end of each quarter, which covers emergency response drills, safe operation procedures, the application of new scientific and technological methods, and the analysis of the most comprehensive safety policies and regulations

in force. With the method of both practical operation and theoretical education, the construction team's risk resistance cognition and coping skills are strengthened. According to a study [17], untrained employees are significantly three times more likely to suffer injury in the course of their work than trained employees, which fully highlights the importance of training in risk management.

In the actual operation stage, the adoption of standardized construction procedures can also significantly reduce the risk. In the construction process of high-voltage power lines, standardized operation processes must be followed, including but not limited to core steps such as pillar erection, wire laying and contact management, which must meet specific technical guidelines, and standardized construction equipment and process procedures are used to ensure that each stage can meet the established safety requirements.

Ultimately, establishing contingency planning is also critical. In order to deal with all kinds of construction accidents that may occur, the construction team should prepare an emergency plan in advance, including information transmission, resource allocation and emergency rescue, so as to ensure that the accident can be promptly and effectively handled and the damage can be minimized. According to statistics, the implementation of emergency plans can reduce the loss after an accident by 30 to 40 percent. Especially in the current situation of climate change, how to properly deal with the unexpected risks triggered by natural disasters has become one of the core challenges in the field of construction management.

To sum up, risk management in the construction of high-voltage power lines is a complex and systematic task, which requires construction enterprises to adopt comprehensive strategies in the aspects of technology application, rules and regulations, staff training and emergency plans. Through continuous improvement of risk management strategies, it can not only effectively maintain the safety in the construction process, but also significantly enhance the overall construction efficiency and reduce economic losses, thus promoting the continued prosperity of construction enterprises.

#### 4.3 Formulation and Implementation of

### **Risk Emergency Plan**

High voltage power line construction involves diverse and complex processes and situations, and the high risk means that it is extremely important to develop and implement effective risk contingency plans. The risk emergency plan involves dealing with the situation quickly and effectively according to the pre-established strategy and action plan when the risk accident occurs, so as to ensure the personal safety of the construction team and the non-destructive state of the power facilities. The establishment and implementation of efficient emergency plan can not only significantly reduce the damage caused by accidents, but also help to improve the safety management efficiency of construction projects. The following are discussed from two dimensions of the formulation principle of the plan, practical methods and concrete examples. When developing a strategy for dealing with emergencies, specific guidelines should be followed. Safety guidelines are a core tenet and emergency plans should ensure that personal safety is given priority in all circumstances. Secondly, in accordance with the integrity criteria, the plan must cover all potential hazards in the construction process, including natural factors (such as lightning, flooding) and human errors and equipment anomalies. The principle of practicality emphasizes that the plan should be concise and clear, easy to implement, and avoid being so complicated that front-line operators cannot quickly put it into practice. To sum up, the dynamic principle advocates that the plan should be adjusted accordingly with the evolution of the construction process and the revision of the risk assessment.

For the strategy implementation stage, the first to build a sound emergency management system, clear the division of responsibilities at all levels and positions. The construction project Department shall set up a professional emergency management department, whose responsibilities cover daily risk monitoring and emergency response, and shall assign managers, technical support teams and on-site implementation teams to ensure rapid response in case of emergency. Organizing regular emergency exercises is one of the core steps to ensure the feasibility of response strategies. Through practice, the defects of the preset scheme can be revealed and timely adjusted.

According to the Power Industry Safety Production Code, such plans should organize at least two comprehensive exercises per school year, at least one of which needs to be implemented in extreme climates, aimed at strengthening the cooperation and execution ability of construction teams in response to various environmental conditions.

For the preparation of the plan, a comprehensive list of potential emergencies and corresponding treatment strategies should be made. For example, in the construction phase of high voltage power lines, common risk scenarios include line breakage, falling objects from high places and fire. Taking a wire breakage accident as an example, the emergency treatment strategy should include line inspection plan, power outage operation procedure, power recovery plan and site environment restoration procedure. For fire accidents, fire monitoring system should be established, immediate alarm procedures should be established, and fire equipment configuration and operation guidelines should be provided.

In practice, the analysis of past high-voltage power construction safety accidents has become a key reference for building effective emergency strategies. For example, in the case of power outages caused by unexpected lightning strikes during the construction phase of certain UHV projects, it can be found that the power supply is interrupted for several hours due to damage to the power lines, resulting in a direct economic loss estimated at about \$1 million. After refining the experience of this plan, it improves the lightning protection design efficiency of the line, strengthens the accident reporting and emergency repair process, and thus reduces the probability of project delay by 15%.

After the implementation of the emergency strategy, the general contractor of the construction should carry out a detailed accident review and plan evaluation, in order to deal with similar challenges more maturely and effectively in the future. The evaluation report shall comprehensively cover the analysis of the origin of the situation, the evaluation of the effectiveness of the response, the constraints in the rescue operation and the optimization plan, and shall be presented to the senior management team on a regular basis.

Finally, in order to enhance the management

and implementation efficiency of emergency plan, it is necessary to strengthen the education and training of emergency management system. The building contractor should periodically invite safety consultants to conduct seminars and organize rich training camps with extensive participation in the areas of risk identification, emergency response, psychological support, etc., with a view to enhancing the safety awareness and crisis management capabilities of all members.

In the process of construction of high voltage power lines, it is very important to formulate and implement risk emergency countermeasures to ensure construction safety and improve management efficiency. Through comprehensive planning, flexible and efficient operation practices, together with continuous improvement of governance procedures, construction teams can more effectively ensure the safety of construction personnel and the smooth operation of equipment in complex construction scenarios.

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