Typical Scenarios and Countermeasures for Power Grid Construction in the Extraordinary Development Stage

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Abstract. Power grid construction is the core link that forms the physical foundation of the power grid and plays an important role in the high-quality development of the power grid. Currently, power grid construction has entered a stage of extraordinary development, and the typical scenarios it faces are also changing. Facing the future, only by clarifying the typical scenarios of power grid construction in the new stage and grasping new challenges and impacts can we scientifically formulate response plans. This study analyzes six typical scenarios of power grid construction in the extraordinary development stage, namely extreme natural disasters, non-traditional geological environment, micro-terrain and micro-climate, stakeholder coordination, equipment quality and supply, and construction leapfrog. It also proposes countermeasures from three aspects: technical empowerment, collaborative linkage, and full-chain management and control to better serve the high-quality construction of the power grid.

Keywords: Power Grid Construction, Extraordinary Development, Typical Scenarios, Countermeasures.

1 Introduction

Power grid construction is the core business of power grid enterprises and is the material foundation and important guarantee for the high-quality development of power grids. As the construction of new energy systems and new power systems accelerates, power grid construction has entered an extraordinary development stage of large-scale centralized construction, high-intensity innovation and research, and high-quality transformation and upgrading. In the long term in the future, the overall pattern of "transmitting electricity from west to east" across the country will not change. New energy will become the main body of installed capacity in the power system, and the development of inter-provincial power transmission will be further accelerated. In the future, the unconventional development of power grid construction will continue for a long time, and some unconventional scenarios will gradually evolve into conventional scenarios. Scientifically describing typical scenarios of power grid construction and analyzing the main characteristics and important impacts of typical scenarios are of major practical significance for scientifically arranging power grid construction work and promoting high-quality construction of power grid projects.

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Dong Hechun et al. (2025) deeply explored the application scenarios of intelligent technologies in the field of power engineering[1]. Li Qing et al. (2025) based on scenario division, analyzed the application and cost of artificial wetland engineering technology, and believed that there was a good positive correlation between engineering investment and construction scale in different scenarios[2]. Wu Yongquan et al. (2022) proposed a visualization hierarchical early warning model for transmission line corridors combined with scenario analysis, which accurately reflected the hidden danger early warning status of transmission line corridors[3]. Liu Meixia et al. (2022) analyzed typical scenarios such as multi-disciplinary collaborative modeling, full-process simulation rehearsal, cost analysis based on BIM models, and strengthened design interface management in the digital design of nuclear power construction projects[4]. Zhang Chenggeng et al. (2022) focused on analyzing the advantages of intelligence and informatization brought by innovative application scenarios of unmanned aerial vehicles in construction projects, such as measurement, process management, and fire management, and looked forward to the development prospects of innovative applications of unmanned aerial vehicles in the construction field[5]. Lin Zhi et al. (2018) conducted a risk assessment study on the operation period of one of the recommended route schemes for a certain cross-sea tunnel, and designed possible major risk event scenarios during the operation period[6].

This study describes typical scenarios in the extraordinary development stage of power grid construction, analyzes the main difficulties and challenges existing in various scenarios, and proposes measures and suggestions to deal with problems in various scenarios to better support the high-quality construction of power grid projects.

2 Description of Typical Scenarios of Power Grid Construction

Combined with the investigation of different regions and different types of power grid projects, this study believes that there are six main typical scenarios for power grid construction in the extraordinary development stage.

2.1 Extreme Natural Disasters

Due to intensified global warming, active geological activities, and superposition of climate phenomena, extreme natural disasters such as meteorological disasters, geological disasters, fires, and biological disasters have become more frequent. They are sudden, unpredictable, and force majeure, and have serious impacts on the safety of personnel in power grid construction and the access of construction materials.

The main characteristics are: suddenness, unpredictability, force majeure and profound harm.

The main impacts include: The impact of natural disasters on power grid construction is mainly concentrated in schedule extension, equipment damage, personnel injuries, etc. Extreme rainfall causes early survey and construction progress to be extended; wind disaster causes towers to tilt or collapse, and the stability of spans, cables, etc.

needs to be checked; ice dancing increases the load on wires, towers, hardware, etc., leading to risks such as tower collapse and disconnection; lightning strikes cause transmission line insulators to flashover and people to suffer lightning strikes, etc.; medium- and high-intensity earthquakes cause equipment damage, transmission lines collapse, towers break, etc.

2.2 Non-traditional Geological Environment

Power grid construction has entered regional blank areas and construction no-man's land on a large scale, and more construction operations are carried out in non-traditional geological environments such as high altitudes, sandy deserts, perennial strong winds, and rivers and coasts. The special terrain and special meteorology are superimposed, and the historical geological and meteorological data are lacking, which has a serious impact on the construction platform development, foundation stability, transportation, and personnel operation risks of power grid construction.

The main characteristics are: special geological environments often overlap with special meteorological conditions (for example, in addition to their own cliffs, moving glaciers, perennial frozen soil, etc., alpine areas are often accompanied by high cold, and Gobi desert areas are often accompanied by excessive temperature differences). Some areas are in uninhabited land, lack historical meteorological and hydrological data, and have no infrastructure such as power supply, water supply, accommodation, and communications. The special climate environment has a direct adverse impact on the physiological state of personnel and the operation of equipment.

The main impact is: severe temperature differences will cause thermal expansion and contraction of metal materials such as transmission tower components and welded joints, which may cause component deformation and loose connections, making it more difficult to control installation accuracy; construction equipment such as generators and water pumps are prone to startup difficulties, reduced operating efficiency and even shutdowns in low-temperature and low-oxygen environments, affecting the advancement of key processes such as drilling and hoisting. The geology of the plateau Gobi is hard and there may be frozen soil layers. Foundation construction processes such as drilling and excavation require more manpower and equipment power. Moreover, the melting of frozen soil layers can easily lead to foundation settlement, which places higher requirements on the load-bearing stability of tower foundations. A low-oxygen environment can easily cause altitude sickness among construction workers, causing symptoms such as headaches and fatigue. This not only reduces their working ability, but may also induce life-threatening conditions such as acute altitude sickness. Large temperature differences between day and night can easily lead to health risks such as colds and frostbite. The lack of communication signals leads to information interruption between the site and the outside world and between various operating points. If emergencies such as equipment failure, personal injury, sudden weather disasters, etc., it is impossible to call for rescue or transmit information in time, and the emergency response lags behind, which may amplify the consequences of the accident. Extremely poor road conditions make it easy for vehicles to get stuck and goods to slip during the transportation of construction equipment and building materials. This not only causes material damage and transportation delays, but may also cause traffic safety accidents.

2.3 Micro-topography and Micro-meteorology

Local sections within a large area of power grid construction form special meteorological areas that are significantly different from the surrounding large areas due to factors such as terrain, location, slope, temperature, humidity and other factors. They present characteristics such as small scope, high hazards, and difficulty in surveying during the design stage, which have a serious impact on the construction safety risks of power grid construction and the execution of design plans.

The main characteristics are: local special weather has a small scope and great harm, and is not easy to be surveyed during the design stage.

The main impact is: micro-topography and micro-climate in local areas form a small-scale special geological environment, which causes insulator tripping failures due to pollution, moisture and other reasons, resulting in greater insulation safety hazards. The current wind deflection faults caused by local extreme winds are characterized by multiple points, wide areas, and high frequency, which have a greater impact on the safe operation of the line. Operation requirements for existing design wind speed values and air gap verification have been further increased. The requirements for meteorological surveys, diversification of design plan demonstration methods, lean design results, and standardization of construction have become more stringent. The existence of local micro-topography and micro-climate such as passes, canyons, and mountain watersheds is conducive to the generation, development, and aggravation of line ice covering and strong winds.

2.4 Stakeholder Coordination

Governments, special organizations, railways, highways, mines, and other stakeholders involved in power grid construction are affected by social changes, institutional environment, and psychological needs. Government regulatory requirements and law enforcement have become stricter, external entities interact more frequently with power grid construction, and public opinion risks have increased. The interest coordination tasks in the early stage, construction stage, and acceptance stage of power grid construction projects have become more arduous.

The main characteristics are: there are differences or even contradictions in the interests and needs of multiple parties.

The main impact is: Government supervision at all levels is becoming more and more stringent. Power grid construction faces multiple administrative approvals for land, military, navigation and flood control, involving government departments at all levels, and external coordination tasks are arduous. The state strictly manages and approves situations that cross ecological environment protection zones, and it is "hard to obtain a certificate" for environmental impact assessment and water conservation approvals for some cross-provincial projects. Cross-operational construction cooperation is becoming increasingly closer, the power transmission and transformation engineering market is opening up in an orderly manner, and more and more business entities and social entities are participating in power grid construction. Highways, railways, oil and gas, municipal pipeline networks and other operating entities have complex interactions and coordination relationships.

2.5 Equipment Quality and Supply

With the large-scale and intensive construction of power grid projects, the demand for key materials and components at each stage has increased. The production capacity of the whole machine has become saturated, and key components have become constraints. The research and development of domestic equipment has lagged behind. The difficulty of product supply configuration and equipment quality control has increased, which has an important impact on the quality and progress of power grid projects.

The main characteristics are: the level of electrical equipment manufacturing cannot keep up with the development of construction needs.

The main impact is: equipment manufacturers have tight supply balance and weak anti-interference. It is difficult to fully guarantee the production and service needs of each project under the simultaneous multi-line tasks. Lagging progress of converter equipment and tight supply are common phenomena, which forces companies to monitor materials, arrange plans, and accelerate progress upstream. my country's high-end power transmission and transformation equipment industry chain has basically achieved domestic manufacturing at the system design and equipment level. However, supporting raw materials such as zero-magnetic CT flux equipment, high-end converter valve side bushings and tap-changers are still highly dependent on imports. The safety and stability of the supply chain has become a key point in power grid construction, and there is a risk of "small links kidnapping the big chain". Large-scale construction equipment companies have insufficient understanding of power grid construction scenarios and functional requirements. Due to insufficient profit margins in market segments, they are not highly motivated to innovate proactively and have insufficient support from the industrial ecosystem. The quality of some domestic substitute products lags far behind imported products, and market choices are still “foreign-based.” The workload of manufacturing and installing UHV main equipment has surged, resulting in a shortage of skilled technicians and weakened quality control, which has affected equipment supply and quality stability.

2.6 Construction Span

Construction across rivers and mountains can only be carried out "from the sky to the ground". There are more and more ultra-tall tower installations, ultra-large span wiring, overall line relocation, GIL pipe corridor construction and even directional blasting operations. The power plan involves a large amount of coordination within the system and outside the system. The difficulty of power grid construction project design, cross-construction technology research, and obtaining blackout construction time has greatly increased.

The main features are: the corridor resources are extremely scarce, and the implementation of the spanning plan is extremely difficult.

The main impact is: the spanning plan can only "go to the sky and go to the ground". There will be more and more ultra-high tower installations, ultra-large span wiring, overall line relocation, GIL pipe gallery construction and even directional blasting operations, and the difficulty of power grid construction will rise significantly. The construction span involves power outages, reconstruction, and overlapping of more than ten lines ranging from 110 kV to 500 kV. The power outage plan has a significant impact on the security of the power grid, and the construction plan and temporary overlapping are extremely complicated. The corridor is very crowded, with many surrounding sensitive factors and prominent coordination conflicts. Work interruptions during the construction process have a great impact on the construction period and public opinion.

3 Countermeasures for Typical Scenarios of Power Grid Construction

In order to improve the quality and efficiency of power grid construction in the extraordinary development stage, a systematic optimization and improvement system needs to be built around the three core dimensions of technological empowerment, collaborative linkage, and full-chain management and control.

At the technical level, a multi-source meteorological and geological early warning platform was built and monitoring data was integrated to achieve accurate predictions, and ice-resistant and lightning-proof conductors and modular pole towers were simultaneously used to strengthen engineering stress resistance; refined survey work was carried out, drones and geological radars were used to supplement data shortcomings, construction equipment was improved for special environments and supporting temporary support facilities were also optimized, and the "high-to-the-ground" construction plan was optimized to reduce the impact of power outages with the help of intelligent technology.

At the collaborative level, a government-enterprise collaboration mechanism is established to simplify the cross-regional and cross-department approval process, and proactive disclosure of project information opens up public communication channels to resolve public opinion risks; the collaboration of the industrial chain is strengthened, supporting the research and development of domestic core components and establishing a strategic reserve, and coordinating internal and external resources within the system to ensure construction progress.

At the management and control level, we strictly implement the equipment entry inspection system, implement full-process quality control traceability, improve the emergency plan system, form closed-loop management through multi-dimensional measures, and comprehensively solve various pain points and problems in power grid construction.

4 Conclusion

Under the extraordinary development stage, power grid construction is of great practical significance in ensuring power supply security and serving energy transformation and development. This study systematically analyzes the six typical scenarios that power grid construction will face in the long term in the future, analyzes the typical characteristics and main impacts of various scenarios, and puts forward some suggestions from the three main levels of technology, collaboration, and management and control.

In the next step, during the specific construction process of various projects, we can combine the scenarios and strategies proposed in this study to propose more detailed and practical response plans, and continue to accumulate excellent practices and experience in dealing with new scenarios.

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