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Contractual Governance of Cost Risk Allocation in Power Engineering Projects under the EPC (Engineering, Procurement, and Construction) Contracting Model

Weiwei Wang[1], Yingle Zhuang[2]
[1]Engineering Economics Institute, Hebei Branch, China Nuclear Power Engineering Co., Ltd, Shijiazhuang 050000, Hebei, China
[2]Design Management Department, Hebei Branch, China Nuclear Power Engineering Co., Ltd, Shijiazhuang 050000, Hebei, China
Corresponding author: Weiwei Wang (e-mail: lirui0805@163.com)

ABSTRACT Cost risk allocation remains a key challenge in EPC-mode power engineering projects, where technical, market, and operational uncertainties can affect project delivery and lifecycle costs. This study investigates contractual governance mechanisms for optimizing cost risk distribution, using the DART (Definability, Affordability, Responsibility, and Transferability) framework to analyze responsibilities and dynamic pricing adjustments. While the research focuses on traditional EPC project management, the methodology is particularly relevant for electromagnetic engineering projects, such as antenna array installation, RF distribution networks, and high-frequency propagation infrastructure, where cost, schedule, and risk coordination are critical. The proposed framework integrates lifecycle cost management, multilevel performance supervision, and transparent contractual mechanisms to improve risk allocation efficiency and reduce disputes. By combining EPC contractual governance with engineering project management principles, the approach provides an effective strategy for managing cost and performance risks in complex electromagnetic infrastructure projects, ensuring reliable project execution and optimized resource utilization.

INDEX TERMS EPC contracting, contractual governance, cost risk allocation, electromagnetic engineering

I. INTRODUCTION

THE EPC (Engineering, Procurement, and Construction) model is an internationally accepted method for organizing engineering construction, and it has experienced rapid development and widespread application in China's power engineering sector. This model, with its integrated management of design, procurement, and construction, effectively optimizes overall project efficiency; however, it also makes the identification, evaluation, and allocation of cost risks more complex. Power engineering is characterized by large investment scale, high technical requirements, long construction periods, and numerous external influencing factors. Cost risks persist throughout the entire project lifecycle, involving technology, markets, and management. Traditional risk allocation methods are mostly reactive and based on post-event accounting, lacking a systematic mechanism for pre-event prevention and dynamic adjustment, leading to frequent contract disputes and uncontrolled project costs. Contract governance theory provides a new perspective on this issue; sound contract design and institutional arrangements can rationally allocate and effectively control risks.

II. CHARACTERISTICS AND ANALYSIS OF COST RISKS IN POWER ENGINEERING UNDER THE EPC (ENGINEERING, PROCUREMENT, AND CONSTRUCTION) CONTRACTING MODEL

A. TYPES OF COST RISKS IN EPC (ENGINEERING, PROCUREMENT, AND CONSTRUCTION) CONTRACTING MODELS FOR POWER ENGINEERING

The cost risk under the general contracting model of power engineering is multidimensional and hierarchical, reflecting the complex financial uncertainties that also permeate large-scale machinery and infrastructure investments in the industry. The sources of risk are mainly divided into four categories: technical risk, market risk, management risk and external environment risk. While these categories provide a theoretical baseline for identification, they frequently overlap in engineering practice. Specifically, 'Technical Management Risk' is conceptualized as a hybrid category where management deficiencies (such as poor coordination or inadequate review) directly exacerbate technical uncertainties (such as design errors). This integrated view is essential for the later optimization strategies, as it addresses risks that cannot be effectively mitigated through a single-dimension approach. Technical risk is caused by the professionalism and innovation of power engineering, including the uncertainty of new technology application, the quality of design schemes, the maturity of construction technology, etc. This type of risk is directly related to the feasibility and cost level of project implementation [1]. Market risk mainly includes equipment and material price risk, labor cost risk, exchange rate risk, etc. During the project construction period, the unpredictability of market prices leads to serious deviations between the actual project cost and the contract budget [2].

B. CURRENT STATUS OF COST RISK DISTRIBUTION AMONG DIFFERENT CONTRACTING PARTIES

In the practice of power engineering general contracting contracts, the cost risk is uneven and unclear between the owner and the general contractor. Traditional contracts mostly adopt a simple fixed total price or cost plus fee form. The allocation of risk mainly depends on the selection of contract type, without detailed division of specific risks. The owner generally bears macro risks such as policy changes and major scope shifts. However, cost increases stemming from insufficient design depth or ambiguous work interfaces—factors often controlled or initiated by the owner's preliminary requirements—frequently lead to disputes [3]. Under the fixed-price model, while the contractor nominally assumes most cost risks, this assumes the contractor has full control over the variables. In practice, the general contractor often passively bears risks—such as those arising from latent site conditions or incomplete owner-provided data—that rational risk allocation principles suggest should be shared. This sharing is justified because the owner is often the 'least-cost avoider' for these specific risks; forcing the contractor to bear them alone lead to excessive risk premiums and adversarial disputes that undermine project stability [4].

C. PROBLEMS WITH THE CURRENT COST RISK ALLOCATION MECHANISM

There are three main problems with the current cost risk allocation mechanism for power engineering general contracting contracts. First, the risk identification is insufficient. Before the contract is signed, the risk is not systematically identified and classified, and the types of risks, the degree of impact, and the probability of occurrence cannot be accurately determined, resulting in the contract terms not covering all risk situations [5]. Second, the allocation principle is unclear. The contract only stipulates some general principles and lacks specific standards and quantitative indicators that can be operated. When a risk event occurs, it is difficult to quickly determine the responsible party and the sharing ratio, causing a lot of disputes. Third, there is a lack of a sound adjustment mechanism. To resolve this, the proposed optimization strategy utilizes LCC metrics to justify a 'Target Cost + Incentive' fee structure. Instead of a rigid fixed price that ignores long-term value, the contract price is adjusted based on the 'Total Cost of Ownership' (TCO). This allows for a higher initial CAPEX—and thus protected contractor margins—if the contractor implements high-quality materials or innovative designs that reduce the net present value (NPV) of future energy losses and maintenance. Most contracts adopt a fixed-price method without dynamic response strategies for market fluctuations. While a fixed price is intended to provide the owner with budget certainty, it can become economically inefficient when extreme volatility occurs. If the risk exceeds the contractor's financial capacity, it leads to performance failure or 'corner-cutting' in quality. Therefore, contractual governance argues for a transition from a 'static fixed price' to a 'dynamic target price' for specific volatile elements. This ensures the contractor is not penalized for macroeconomic factors beyond their control, while preventing the owner from paying an unnecessarily high risk premium embedded in the initial bid [6].

III. THE MECHANISM OF CONTRACTUAL GOVERNANCE IN THE ALLOCATION OF COST RISKS IN POWER ENGINEERING

A. THE IMPACT OF CONTRACTUAL GOVERNANCE ON THE EFFICIENCY OF RISK ALLOCATION

Contractual governance relies on a complete institutional arrangement and constraint mechanism, which can significantly improve the overall effectiveness of risk sharing in power engineering cost. Implementing systematic risk allocation according to the four basic principles of the DART risk sharing model can achieve better risk control and better match the risk management capabilities and responsibility boundaries of all parties. To provide a complete methodological framework, the four dimensions are defined as follows: (1) Definability (D) ensures the risk scope and boundaries are clearly delineated to avoid interface disputes; (2) Affordability (A) identifies the party with the greatest economic and technical capacity to absorb the risk; (3) Responsibility (R) assigns liability to the party whose decision-making or execution most directly influences the risk outcome; and (4) Transferability (T) determines whether the risk can be mitigated through external instruments such as insurance or hedging. This holistic DART approach transforms risk allocation from a binary 'owner vs. contractor' choice into a multi-dimensional optimization process. The affordability principle stipulates that who manages the risk depends on who has the control capability. In the ±800kV flexible DC project, the contractor mainly manages controllable risks such as construction technology and subcontractor management, while the owner bears external risks such as changes in policies and regulations [7]. The liability principle allocates responsibility according to the causal relationship of the behavior. The rework cost caused by the contractor's design error shall be borne by the contractor, and the loss caused by the owner's incorrect information shall be borne by the owner [8]. The application cases of DART risk sharing model are shown in Table 1:

B. THE VALUE OF CONTRACT DESIGN IN RISK IDENTIFICATION AND PREVENTION

Scientific contract design provides institutional guarantees for the identification and proactive prevention of power engineering cost risks. In terms of risk identification, complete contract terms should include a risk list including technical risks, price risks, scope change risks, performance payment risks and external force majeure risks. In the high voltage DC project, China Southern Power Grid included 6 major categories and 36 minor items of work scope for system research and complete design for the first time, thereby preventing boundary disputes during later execution. In terms of the characteristics of power engineering technology, market factors, and long construction period, a classified and graded risk management system should be created in the contract [9]. Contract design creates a full-process control mechanism of pre-agreement, in-process supervision and post-relief. Pre-agreement relies on detailed provisions on work scope, technical standards and pricing basis. China Southern Power Grid added 11 categories and 79 pricing basis for new technologies such as ± 800 kV flexible DC, filling industry gaps and reducing uncertainty from the source [10]. The contract control mechanism and implementation analysis of major power grid projects are shown in Table 2:

C. PATHWAYS FOR CONTRACT GOVERNANCE TO PROMOTE OPTIMIZATION OF ENGINEERING COST MANAGEMENT

Contract governance promotes the transformation of power engineering cost management from the original post-accounting method to a lean control model throughout the entire process through three main approaches. The first approach is information transparency, which clearly stipulates the information disclosure responsibilities of both parties in the contract terms, creates transparent communication channels, and reduces the probability of opportunistic behavior caused by information asymmetry. The current power industry is moving from "post-accounting" to "pre-prediction, in-process control, and post-evaluation". The "asset life cycle cost library" built by China Southern Power Grid enables the prediction and optimization of operation and maintenance (O&M) costs over several decades during the infrastructure phase. While the EPC contractor is primarily responsible for Capital Expenditure (CAPEX), this LCC data serves as a benchmark for 'Performance-Based Contracting.' In this model, the total contract price remains focused on construction, but incorporates 'Reliability-Linked Incentives.' This means the contractor's profit is partially tied to meeting technical specifications that are mathematically proven to reduce future O&M burdens, rather than holding the contractor liable for the actual O&M costs decades later. Contractual governance provides the institutional foundation for this integration [11]. The second approach is incentive compatibility, which uses a scientific risk-sharing and benefit-sharing mechanism to make the goals of all parties more consistent, thereby generating endogenous motivation to control costs and improve quality. Reasonable contract design links the interests of contractors with performance indicators such as cost savings, shortened construction period, and improved quality, effectively mobilizing the enthusiasm of contractors for proactive management. The third approach is digital management, which involves using contract governance and digital tools to collect, analyze, and provide early warnings of cost data in real time [12].

IV. OPTIMIZATION STRATEGY FOR COST RISK ALLOCATION IN POWER ENGINEERING BASED ON CONTRACT GOVERNANCE

To systematically demonstrate the implementation path of contract governance for the allocation of costs and risks in power engineering projects, this paper constructs a three-tiered, progressive optimization process covering contract clause construction, dynamic adjustment mechanisms, and a supervision and resolution system (see Figure 1). This process embodies the full-process management logic from risk identification and classification, dynamic monitoring and response to performance supervision and assurance, providing an operable risk management framework for power engineering EPC projects.

A. CONSTRUCTING SCIENTIFIC AND REASONABLE RISK-SHARING CONTRACT TERMS

Scientific risk-sharing contract clauses should reflect systematicness, pertinence and operability. In terms of technical and management risks, the contract must define pricing standards for new technologies to prevent disputes. To reconcile the fixed-price structure with fair risk sharing, value engineering clauses should be implemented. These clauses justify the 'sharing' of risk by aligning it with the sharing of rewards: if a contractor optimizes design to reduce cost, they share the savings; conversely, if the owner provides more accurate data to reduce uncertainty, the risk premium is lowered. This shifts the logic from a zero-sum fixed-price transfer to a collaborative efficiency model. At the same time, a joint design review mechanism should be established so that the owner and contractor can jointly evaluate the technical and economic feasibility of the design scheme and control technical risks from the source. Second, in terms of price and market risks, the contract should set up a price adjustment formula [13]. Specifically, a Price Adjustment Factor (P) should be calculated using the weighted average of key material indices:

$$P = \sum \left(\omega_i \times \frac{I_t}{I_o} \right) \tag{1}$$

TABLE 1. Application Cases of the DART Risk Sharing Model

Risk sharing principle	Principle definition	Typical application cases	Risk bearer	Specific risk types	Control measures
Definability (D)	Ensuring risk boundaries are distinct and measurable.	±800KV Flexible DC Project	contractor	Construction technology risks and subcontractor management risks	Technical solution review and subcontractor qualification verification
Affordability (A)	Risk is managed by the party with control over it.	±800KV Flexible DC Project	owner	Policy and regulatory changes, external environmental risks	Policy tracking mechanism and emergency response plan
Responsibility (R)	Assigning liability based on causal influence.	General Engineering Projects	contractor	Rework due to design flaws	Design review system, liability insurance
Transferability (T)	Evaluating the feasibility of risk shifting via insurance/hedging.	Large-scale equipment procurement	owner	Losses caused by providing incorrect information	Document review process and loss compensation mechanism

TABLE 2. Analysis of Contract Control Mechanisms and Implementation in Major Power Grid Projects

Control phase	Control mechanism	Typical Case	Specific measures	Implementation effect	Innovation
Prior Agreement	Detailed definition of work scope	China Southern Power Grid High Voltage Direct Current Project	The contract includes 6 major categories and 36 sub-categories of work related to system research and complete system design.	Preventing boundary disputes	For the first time, the scope of work was systematically defined.
Prior Agreement	Standardization of pricing basis	China Southern Power Grid ±800kV Flexible DC Project	11 new categories and 79 new pricing bases	Filling industry gaps and reducing uncertainty	Establish a pricing system for new technologies
In-process supervision	Milestone Node Management	State Grid Jiangsu Information & Communication Company	integrated business and finance platform provides full-process visibility and control.	Achieve "swift and timely final settlement of project completion accounts."	Real-time monitoring of digital platform
In-process supervision	Regular reporting and inspection	Capital Project Management	Monthly/quarterly reports, key milestone inspections and acceptance	Detect and correct deviations in a timely manner	Dynamic tracking and adjustment mechanism
Post-event relief	Change the claims mechanism	General Electric Power Engineering	Change procedures, claim time limits, dispute resolution clauses	Protect the legitimate rights and interests of both parties	Standardized processing procedures
Full lifecycle optimization	Full life cycle cost management	Southern Power Grid Asset Management	Asset lifecycle cost database, predicting decades of operation and maintenance costs during the infrastructure phase.	Optimize investment decisions and total contract price	Shifting from "post-event accounting" to "whole-process prediction"

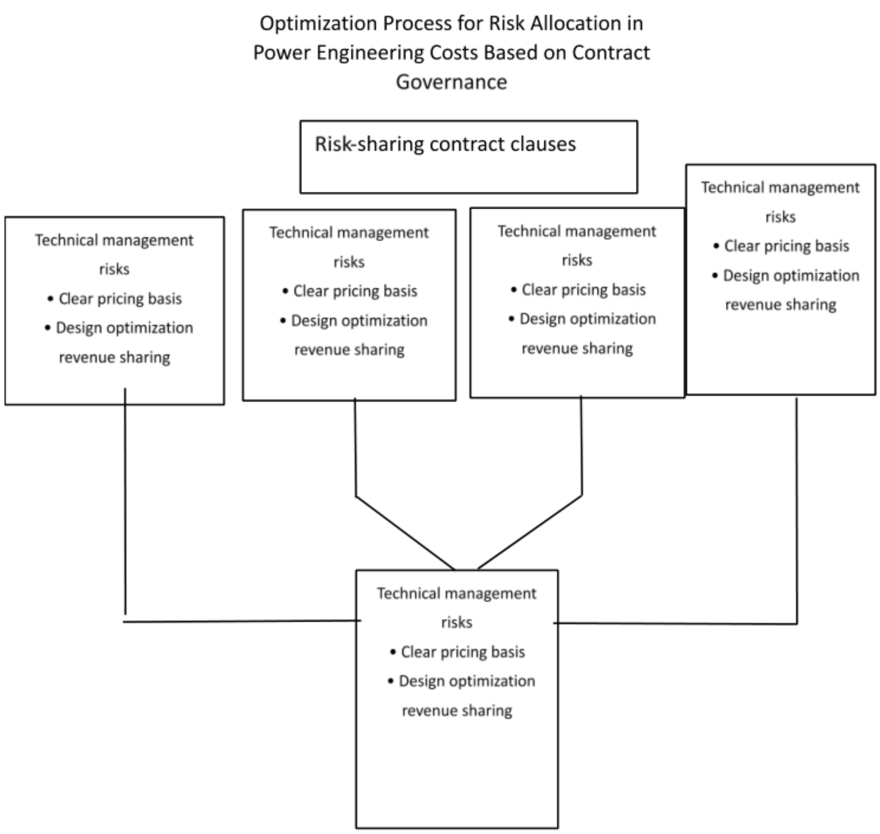

FIGURE 1. Flowchart of Dynamic Cost Risk Adjustment Mechanism

where ω_i represents the weight of material i, I_t is the current price index, and I_o is the base period index. To ensure operability, the contract must define a 'Risk Buffer Zone' (typically ±5%). Within this range, the contractor bears the cost; fluctuations exceeding 5% trigger an automatic adjustment where the owner covers 80-90% of the excess. Furthermore, 'Value Engineering' rewards should be quantified: contractors should be entitled to 30-50% of the audited net savings generated from design optimizations that do not compromise technical standards. The formula should refer to the price index of main equipment and materials for power engineering published by authoritative institutions to ensure the objectivity and fairness of price adjustment. For huge price fluctuations that exceed the agreed range, a renegotiation trigger mechanism and emergency handling procedures should be set up. Again, in terms of scope and change risks, a detailed work scope statement must be prepared to refine the scope of the project, technical standards and functional requirements as much as possible to reduce misunderstandings during the execution of the contract [14]. To clarify the reform direction and core value of contract governance, this paper compares the differences between the traditional model and the contract governance model from four dimensions: risk identification, responsibility division, adjustment mechanism, and supervision system, as shown in Figure 2.

B. ESTABLISH A DYNAMIC COST RISK ADJUSTMENT MECHANISM

A dynamic cost risk adjustment mechanism is essential for ensuring effective responses to uncertainties during the construction of power projects. This mechanism should encompass three main aspects: risk monitoring, early warning response, and adjustment decision-making. For risk monitoring, a real-time monitoring system should be established using digital technologies to continuously track key indicators such as material price indices, project schedule deviations, and cost expenditures. Big data analytics and artificial intelligence algorithms should be used to build cost risk prediction models, identifying potential sources of cost overruns and market fluctuations. Monitoring data should be regularly shared between the owner and contractor to ensure a shared understanding of the project's status. For early warning response, the contract must stipulate quantifiable 'Trigger Points' (TP) based on the Cost Performance Index (CPI) and Schedule Performance Index (SPI). An early warning is automatically initiated when:

1) Cost Variance (CV) exceeds 3% of the monthly budget.
2) The Price Index of a single core material (e.g., copper or steel) fluctuates by more than 10% within a single quarter.
3) Critical path delays exceed 5% of the total project duration.

These quantitative benchmarks transition the mechanism from subjective judgment to automated, data-driven governance. Different response measures are taken based on the risk level. Minor risks are resolved through coordination by project management, while major risks are reported to the decision-making level to initiate a formal adjustment procedure. The early warning mechanism should be integrated with the project's regular meeting system to ensure timely transmission and handling of risk information. For adjustment decision-making, an evidence-based price adjustment mechanism should be established, clearly defining the required documentation, review standards, and approval authority for price adjustment applications. For price adjustments caused by market price fluctuations, the power construction project cost index published by an authoritative institution should be used as the basis for adjustment. Design changes and increases or decreases in project volume shall be settled according to the agreed pricing method and fee rate standard [15].

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C. IMPROVE THE SYSTEM FOR SUPERVISING CONTRACT PERFORMANCE AND RESOLVING DISPUTES

To quantify 'performance success,' the system should utilize a weighted scoring matrix (0-100) assessing quality (40%), schedule (30%), and cost control (30%). Disputes regarding 'unforeseen conditions' should be settled using a 'Quantified Impact Analysis': claims are only valid if the event causes a cost increase exceeding 0.5% of the total contract value or a delay of more than 10 working days . This ensures that only significant, measurable risks trigger formal dispute procedures, reducing transaction costs.

An effective contract performance supervision and dispute resolution system is the institutional guarantee for ensuring the implementation of the cost risk allocation mechanism. Regarding performance supervision, a multi-level and comprehensive supervision system should be established. First, a digital collaborative supervision platform should be established, utilizing an integrated business and finance system to solidify the contract execution process, achieving real-time visual management of information such as project progress, cost expenditure, and payment. The platform should have an automatic early warning function, promptly alerting relevant personnel when deviations occur from the agreement. Second, a sound regular inspection system should be established, with the owner and contractor jointly conducting joint inspections of project quality, progress, and costs according to the time nodes stipulated in the contract, checking whether risk control measures are implemented. Inspection results should be documented in writing, serving

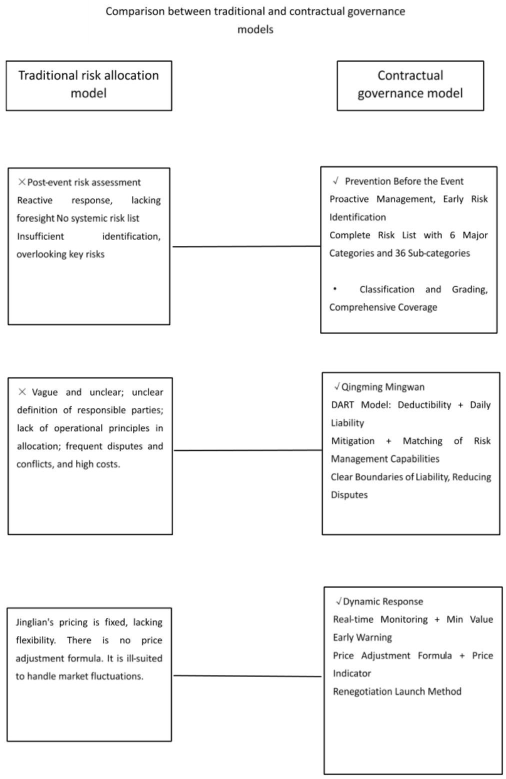

FIGURE 2. Comparison between the traditional model and the contractual governance model

as the basis for future settlement and liability determination. A third-party supervision mechanism should be introduced to provide objective evaluations. To quantify 'performance success,' the system should utilize a weighted scoring matrix (0-100) assessing quality (40%), schedule (30%), and cost control (30%). Disputes regarding 'unforeseen conditions' should be settled using a 'Quantified Impact Analysis': claims are only valid if the event causes a cost increase exceeding 0.5% of the total contract value or a delay of more than 10 working days. This ensures that only significant, measurable risks trigger formal dispute procedures, reducing transaction costs associated with minor disagreements. A diversified and multi-level mechanism should be established for dispute resolution. Contract governance constructs a systemic risk management system through three pillars, the internal logical relationship of which is shown in Figure 3.

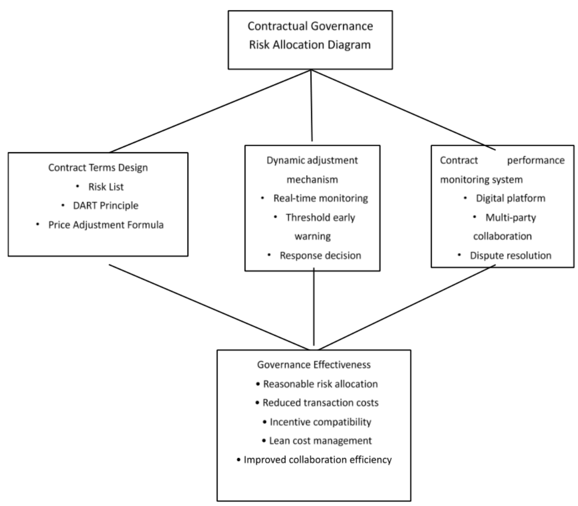

FIGURE 3. Risk Allocation Relationship in Contract Governance

V. CONCLUSION

The reasonable sharing of cost risks in power engineering projects under the EPC (Engineering, Procurement, and Construction) model is a crucial guarantee for the smooth progress of the project. Contract governance, as a systematic institutional arrangement, provides an effective way to solve the problem of cost risk allocation through scientific risk identification, reasonable allocation of responsibilities, and timely adjustment and improvement of the supervision system. This paper, based on the characteristics of cost risks in power engineering, systematically discusses the mechanism of contract governance and proposes optimization strategies from three aspects: contract terms, dynamic adjustment mechanisms, and performance supervision systems. From a practical perspective, integrating the concept of contract governance with digital and intelligent technologies to create a risk prevention and control system that is interconnected—comprising a clear contract structure, real-time data support, and collaborative management processes—can significantly improve the rationality and effectiveness of cost risk sharing, a proactive, integrated approach equally vital for minimizing financial exposure in the highly automated and technology-dependent capital projects .

AUTHOR CONTRIBUTIONS

Conceptualization –Weiwei Wang and Yingle Zhuang; methodology – Weiwei Wang and Yingle Zhuang; investigation – Weiwei Wang and Yingle Zhuang; writing-original draft preparation – Weiwei Wang and Yingle Zhuang. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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