Research on Sustainable Management Strategy of General Contracting Project of Power Generation Project under the Background of Green Energy Transformation

Chunyu Zhao[1], Jingyu Zhao[2]

[1] *State Nuclear Electric Planning Design & Research Institute Co., LTD, Engineering Construction Branch, Beijing 100095, China*
[2] *State Nuclear Electric Planning Design & Research Institute Co.,LTD, Planning and consulting Branch, Beijing 100095, China*
[1] *Email: 13810280144@163.com*
[2] *Corresponding Author. Email: zjy1228@126.com*

ABSTRACT
With the profound transformation of global energy system to clean and low carbon, power generation projects, as the core of energy infrastructure construction, are facing the theoretical tension between sustainable development goals and traditional management models. The existing research mostly focuses on technical path or policy effect, and lacks systematic discussion from the perspective of project management ontology. This article aims at responding to this challenge in theory, revealing the contradictory mechanism between the external environment drive and the endogenous limitation of management through logical deduction and concept discrimination, with special emphasis on the theoretical path of internalization of environmental externalities. On this basis, a theoretical model of sustainable management covering multi-dimensional target collaborative evaluation, whole life cycle stage mapping and dynamic risk adaptation mechanism is constructed. The article further puts forward the integrated strategy based on value creation, ecological collaborative governance of supply chain, organizational resilience enhancement and digital decision support. By reconstructing management logic and factor allocation, the conflict between construction efficiency and ecological performance can be effectively reconciled, and the project management paradigm can be promoted to transition from single economic orientation to comprehensive value creation.

Keywords: *Green energy transformation, General contracting of projects, Sustainable management, Management path.*

1. INTRODUCTION

At present, the global energy system is undergoing profound structural changes. Guided by the strategic goal of “peak carbon dioxide emissions, carbon neutral”, building a clean, low-carbon, safe and efficient energy system has become an international consensus [1]. As a key area of carbon emissions, the transformation and upgrading of power industry is of decisive significance for realizing the national sustainable development vision [2]. Under this macro background, power generation project, as the core link of energy infrastructure construction, is generally organized and implemented by Engineering-Procurement-Construction (EPC) mode. With the advantage of engineering procurement construction’s integration, EPC model has shown remarkable performance in improving construction efficiency, but its theoretical connotation needs to be reconstructed urgently in the new context of green transformation [3].

With the deepening of green energy transformation, the traditional EPC management mode is facing unprecedented theoretical dilemma and practical tension. Traditional EPC management

logic often focuses on time limit control, cost saving and quality assurance, and follows the principle of local optimization under linear economic thinking. Green transformation introduces new value dimensions such as environmental load minimization, social inclusion and life cycle carbon performance [4]. This superposition and coupling of multi-dimensional goals makes the single economic efficiency orientation incompatible with the complex requirements of sustainable development, and there is a significant disconnect between theory and practice [5]. The existing academic research mostly focuses on the engineering choice of green technology path or the analysis of the economic effect of macro-policy regulation, and few documents systematically discuss how to embed sustainability into the complex contract and organizational governance structure of EPC from the perspective of project management ontology [6]. Especially at the theoretical level, the logical relationship between how to balance short-term construction costs and long-term ecological benefits in an uncertain environment is not clear.

The complexity of management brought by energy transformation goes beyond a single discipline, and it is urgent to integrate the theoretical perspectives of environmental science, institutional economics and management [7]. Therefore, exploring the sustainable management strategy of power generation project under the background of green energy transformation is not only a functional repair of the traditional project management system, but also a theoretical expansion of the discipline boundary of engineering management. This article aims to adhere to the path of theoretical speculation, from a theoretical perspective, deeply analyze the internal contradiction between external transformation driving forces and internal management paradigm, and try to build a set of sustainable management theoretical model that adapts to green characteristics. By clarifying the conceptual boundary and logical mechanism, it will provide solid theoretical support and methodological guidance for subsequent practical exploration and quantitative research, thus promoting the theoretical transition of power generation project management from “construction-oriented” to “value-creation-oriented”.

2. TRANSFORMATION DRIVE AND MANAGEMENT CHALLENGE

The uncertainty of external environment constitutes the core driving force of transformation. The urgency of climate change and the strengthening of carbon constraint policy make the internalization of environmental costs an inevitable trend. On the theoretical level, this means that the criteria for judging the success of the project have fundamentally shifted, and simple economic indicators are not enough to cover the external impact of the project [8]. The rapid iteration of technology increases the information asymmetry of decision-making, which leads to the failure of the traditional forecasting model based on historical data, forcing the management subject to have stronger dynamic adaptability.

The existing management paradigm has endogenous limitations. The traditional EPC contract structure is based on the clear distribution of risks, but many environmental risks in the green transformation are highly vague and unmeasurable, so it is difficult to be completely covered by the existing contract terms [9]. Stakeholder theory shows that in the whole project life cycle, there are often time mismatches and conflicts of interest between the environmental protection demands of the owners during the operation period and the delivery targets of the general contractor during the construction period. This fragmentation of the value chain makes it difficult for the concept of sustainability to penetrate barriers at all stages. In addition, in the face of interdisciplinary and cross-cycle complex tasks, the traditional bureaucratic organizational structure is slow to respond, and it is difficult to support the rapid response needs of green technology innovation.

3. THEORETICAL MODEL OF SUSTAINABLE MANAGEMENT

Based on the analysis of the driving force of transformation and the limitation of management paradigm, it is particularly urgent to construct a set of theoretical model of sustainable management of power generation projects that adapts to the characteristics of green energy transformation. This model is not a simple superposition of traditional project management knowledge system, but a logical framework for reconstructing management elements based on system theory and cybernetics. Its core lies in solving three theoretical problems: multi-objective conflict, full-cycle fragmentation

and uncertain risk, aiming at establishing a management structure with embedded sustainability principles.

In the target dimension, the model advocates the transformation from the traditional "iron triangle" constraint to "3D value synergy" According to the triple bottom line theory, the financial return of the economic dimension is no longer the only priority, but needs to form a dynamic balance with the carbon emission reduction performance of the environmental dimension and the community inclusiveness of the social dimension. Theoretically, there is a nonlinear coupling relationship among them. The initial increase of environmental investment may realize Pareto improvement of life cycle cost through the improvement of later operation efficiency. The guarantee of social compliance is the precondition to reduce the risk of policy friction. Therefore, the management model must introduce the "sustainability weight adjustment mechanism" to dynamically adjust the priority of each goal according to the macro-policy orientation and resource endowment at different stages of the project, so as to maximize the overall value function, rather than local optimization.

In the time dimension, the model emphasizes the stage mapping and interface management of the whole life cycle. Under the traditional EPC mode, there are often information islands in design, procurement and construction, which leads to the environmental cost being locked in the design stage and difficult to correct in the construction stage [10]. This theoretical model puts forward the strategy of "front-end implantation", which reversely transmits the energy output efficiency and decommissioning disposal requirements during the operation and maintenance period to the design and procurement stage. This requires clearly defining the boundary of stage connection in theory and establishing a cross-stage decision feedback loop. In particular, the design link should be regarded as the key control point to determine the ecological footprint of the project, and the management focus should shift from the front-end schedule control to the back-end performance commitment to ensure that the construction results are consistent with the long-term strategic goal of green transformation.

In the dimension of process and risk, the model constructs a dynamic adaptive mechanism based on knowledge flow. The rapid iteration of green technology and frequent changes of environmental laws and regulations make the traditional static risk management theory ineffective. The new management model introduces the variable of "knowledge accumulation", and holds that the project organization should have the ability to constantly correct decisions through information feedback in uncertainty. This means that it is necessary to establish a risk matrix that includes variables such as green technology standard updating and carbon price fluctuation simulation, so as to transform uncontrollable external environmental pressure into internal management indicators. By strengthening the knowledge sharing mechanism within the organization, the decision-making deviation caused by information asymmetry can be reduced, so as to maintain the resilience of the project in an uncertain transition environment.

4. SYSTEM OPTIMIZATION AND STRATEGY PATH

Based on the theoretical model of sustainable management, this section aims to put forward specific optimization strategies and implementation paths from the perspective of system theory. These strategies are not isolated technical means, but logical schemes to reconfigure project management elements, aiming at solving the structural contradictions between theory and practice and ensuring that the green transformation goal can be effectively implemented in EPC projects.

The integrated strategy based on value creation is the core path. Traditional management often regards cost, schedule and quality as competitive constraints, but in the context of sustainability, Pareto improvement of multi-dimensional objectives needs to be realized through value engineering. Theoretically, the design stage has a decisive leverage on the environmental impact of the whole life cycle of the project, accounting for more than 70% of the total carbon emissions. Therefore, the strategic focus should be shifted to the feasibility study and preliminary design. By introducing green design constraints and life cycle cost (LCC) evaluation model, the technical scheme can be optimized at the source. Although this may increase the initial construction capital investment, it can significantly reduce the energy consumption during the operation period and the cost of post-disposal. This strategy requires the establishment of interdisciplinary collaborative decision-making mechanism, breaking professional barriers, ensuring that environmental benefits are quantified and included in the economic evaluation system, so as to maximize the overall system value rather than the extreme of local indicators.

The EPC model involves a huge subcontracting network, and if we only pay attention to the performance of the general contractor, we can't cover the carbon footprint of the whole chain of products. Based on the perspective of transaction cost economics, supply chain management should change from simple contract execution to ecological co-construction. In the strategic dimension, green performance standards and supplier access mechanism need to be embedded in bidding contract, environmental compliance should be regarded as the key weight of performance evaluation, and dynamic reward and punishment clauses can also be introduced into it. At the same time, the knowledge spillover channel has been established, and the green manufacturing capability of upstream suppliers has been helped to improve, and the symbiotic relationship of benefit sharing and risk sharing has also been formed. This process can alleviate the moral hazard caused by information asymmetry, and improve the sustainability of the whole delivery system through the conduction effect of industrial chain, so as to realize the value transition from linear chain to network ecology.

Green technology is iterative rapidly, and the boundary of carbon policy is vague, so the traditional bureaucratic rigid structure is difficult to adapt to the rapidly changing external environment. Theoretically, organizations need to have the characteristics of “duality”, that is, taking into account external adaptability while pursuing internal efficiency. The strategy suggests implementing flexible organizational structure, giving front-line technical teams more technical decision-making power, and shortening the feedback loop of field problems to management. At the same time, the function of organizational learning should be strengthened, a standardized mechanism should be established, and the implicit experience in the process of green transformation should be transformed into explicit knowledge assets. Digitalization is not a simple tool substitution, but an information base for reconstructing management processes. Its theoretical logic lies in greatly reducing information asymmetry through the transparency of data flow and realizing scientific and accurate decision-making. In the theoretical model, the digital platform acts as the hub of information aggregation and value transmission, so that indicators such as environmental monitoring and carbon emission tracking can be fed back to the management center in real time.

5. CASE ANALYSIS

5.1 Green Design Value Creation Case

There is a wind photovoltaic complementary power generation project in North China that uses a full lifecycle carbon assessment model. In the preliminary feasibility study, the project team did not blindly pursue the minimization of construction costs, but introduced quantitative indicators of environmental impact. After conducting multi-objective comparison and selection of different technical solutions, the combination scheme of high-efficiency photovoltaic modules and high-efficiency energy storage systems was finally determined. This decision resulted in an initial investment increase of about 5%, but according to calculations, it was due to improved energy efficiency. Reduce the electricity cost by 8% during the project operation period. At the same time, the design side clarifies the responsibility for the recycling of retired equipment and incorporates the cost of dismantling into the budget system. The implementation results show that the carbon emission intensity during the construction period of the project is lower than the average level of similar projects, which verifies the effectiveness of the front-end implantation strategy. This approach of maximizing long-term benefits through value engineering reflects a shift from a single economic orientation to a comprehensive value creation model.

5.2 Supply Chain Collaboration and Digital Risk Control Case

There is a centralized photothermal power generation general contracting project in the west, which implements the strategy of ecological co-construction in supply chain management. The general contractor embeds the supplier's environmental compliance standards in the bidding documents, and requires major equipment suppliers to issue carbon footprint certification reports. In view of the fast iterative speed of key technologies, the project builds a real-time data monitoring center based on digital platform. This platform can summarize the energy consumption data of upstream equipment manufacturing, logistics transportation and on-site construction. Once the risk of carbon price fluctuation or technical standard change in the supply chain is detected, the management system will automatically trigger an early warning and generate adjustment suggestions. This dynamic adaptation mechanism solves the

problem of traditional static contracts being difficult to cover environmental risks. Through information sharing and knowledge transmission, upstream and downstream enterprises build a community of shared interests and risks. Ultimately, the project achieves both schedule control and ensures the stability and sustainability of the overall delivery system in a complex and ever-changing external environment.

6. CONCLUSION

This article focuses on the sustainable management of power generation EPC project under the background of green energy transformation, and makes a systematic theoretical discussion and logical construction. The research is not limited to the micro-analysis of a single technology or policy, but attempts to reveal the deep predicament and reform direction of the traditional EPC model in the context of the new era from the ontological height of management. Through progressive deduction, this article mainly draws the following core conclusions.

First, the reconstruction of management paradigm is an inevitable requirement of transformation. The uncertainty of external environment forces project management to go beyond the traditional thinking of cost and schedule control and turn to a 3D collaborative system that takes into account economic, environmental and social values. This change is not a simple index increase, but a fundamental shift of value logic, which requires the establishment of a decision-making mechanism that can balance short-term construction interests and long-term ecological benefits and solve the contradiction between linear economic thinking and circular development needs.

Second, the whole life cycle system integration is the core of the theoretical model. It is found that the locking effect of environmental performance at the design end is decisive in theory, so the management focus must be placed first. Constructing a theoretical model including stage mapping, knowledge flow feedback and risk adaptability correction can effectively break the information island, ensure that the concept of sustainability runs through the whole process of project from planning to delivery, and realize the dynamic extension of management boundary.

Third, the system optimization strategy needs a multi-pronged approach. Value integration, supply chain coordination, organizational resilience and digital empowerment constitute the four-dimensional pillars of the strategy. These four contents support each other in theory and point to a more inclusive and adaptive management ecosystem, which provides a methodological basis for dealing with the complex and changeable transformation environment and emphasizes that mechanism design is superior to the application of specific tools.

To sum up, this article tries to provide new perspectives and ideas for the theoretical development in the field of power generation engineering management, hoping to provide reference and enlightenment for subsequent scholars and practitioners to understand and practice management innovation under the background of green transformation, and promote the deep integration of discipline construction and practical application.

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