The Construction of the Scientific and Technological Innovation System in Provincial Power Grid Enterprises: A High-Quality Development Perspective

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Abstract. Amid accelerating global energy transitions and China's national strategies for achieving "dual carbon" goals and building a science and technology powerhouse, provincial power grid enterprises are compelled to evolve into pivotal "innovation sources" and "chain leaders" in technological advancement. However, these enterprises currently face systemic challenges, including rigid disciplinary structures, weak cross-disciplinary collaboration, and inefficiencies in traditional R&D management systems. Specifically, they grapple with integrating high proportions of renewable energy, adopting disruptive digital technologies, and overcoming organizational inertia within traditional utility structures. Leveraging empirical insights from provincial power grids such as State Grid Hubei Electric Power, and drawing parallels with successful innovation frameworks in other sectors (e.g., Huawei's intensive R&D model, Shenzhen's innovation ecosystem), this study constructs a theoretical framework for high-quality innovation system development grounded in innovation ecosystem theory. We propose a "Four-High" innovation system—emphasizing high-impact R&D breakthroughs, high-efficiency management, high-caliber talent cultivation, and high-efficacy technology transfer—to align with the strategic objective of positioning provincial power grids within the "first echelon of State Grid and global top-tier enterprises". Implementation measures include enhancing cross-disciplinary integration, optimizing incentive mechanisms, and fostering industry-academia-research synergies. The study further provides actionable insights on fostering interdisciplinary collaboration within traditional hierarchies through flexible project teams, innovation incubators, and cross-departmental incentives. Policy recommendations emphasize stable investment mechanisms, organizational restructuring, and innovation ecosystem cultivation to ensure sustainable development.

Keywords: High-quality development, provincial power grid enterprises, innovation ecosystem

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1 Introduction

As the global energy transition intensifies, China's "dual carbon" goals and strategy to become a science and technology powerhouse have imparted three critical missions to power grid enterprises. These enterprises must assume the dual roles of "source" and "chain leader" in scientific and technological innovation, fully leverage their roles in technological innovation, industrial control, and security support, and transition from follower innovation to leading innovation. Furthermore, the development of a new power system, dominated by new energy sources, imposes heightened demands on the technological breakthrough capabilities of power grid enterprises. Characterized by "interdisciplinary and multi-subject collaboration", this new power system necessitates the integration of technologies from diverse fields, including meteorology, materials science, and artificial intelligence. However, provincial power grid enterprises are predominantly structured around traditional electrical engineering, exhibiting weak cross-disciplinary collaboration capabilities, which hinders their ability to meet the demands of systematic technological breakthroughs. These challenges manifest in three core areas: 1) Operational-technical: managing real-time grid balance, flexibility, and stability with high renewable penetration, moving beyond the traditional "source-follows-load" paradigm; 2) Technological assimilation: integrating fast-evolving digital technologies like AI, digital twins, and large-scale storage into legacy systems and processes; 3) Organizational-managerial: overcoming the inherent conflict between rigid, vertical hierarchies and the agile, collaborative, risk-tolerant culture required for innovation. Additionally, the traditional scientific research management system is marred by issues such as fragmented organization, inadequate incentives, and low conversion rates of research outcomes, necessitating the exploration of a scientific and technological innovation development model conducive to high-quality development.

Based on existing research outcomes and theories of innovative development, combined with the practical experiences of provincial power grids like State Grid Hubei Electric Power, this paper constructs a theoretical framework for achieving high-quality development in the scientific and technological innovation systems of provincial power grid enterprises. It proposes specific implementation measures, aiming to provide a systematic solution for managing scientific and technological innovation within the power industry.

2 Literature Review

Driven by the objective of high-quality development, research on the technological innovation models of provincial power grid enterprises has gradually emerged as a focal point in academic discourse. Existing research primarily concentrates on the following dimensions:

1. Construction and Optimization of the Whole-Process Innovation System: Trinh et al. (2016) [1] and Bronzini et al. (2016) [2] affirmed the stimulating role of fiscal policies in technological innovation. Yang et al. (2018) [3] introduced the "5U4" regional

collaborative model for the northwest region, which alleviates resource scarcity through joint project applications and achievement promotion, thereby fostering the innovation and transformation of scientific and technological achievements in the northwest power grid. Duan et al. (2024) [4] developed a four-dimensional evaluation index system (research input, output, talent, and transformation) using the AHP method, providing a quantitative assessment tool for innovation efficiency. Fei et al. (2024) [5] constructed a full-chain support system encompassing "science and technology intelligence analysis - project management - technology transfer," addressing the innovation efficiency issues faced by provincial power grid enterprises. Taking State Grid Jiangsu as an example, they highlighted resource dispersion and insufficient coordination as primary bottlenecks, emphasizing the need to strengthen cross-departmental collaboration mechanisms.

2. Innovation Path of Green and Low-Carbon Technologies under "Dual Carbon" Goals: Focusing on the "dual carbon" goal strategy, several scholars have explored the innovation path and challenges associated with green and low-carbon technologies. They proposed a two-way path of "top-down theoretical support + bottom-up practical exploration," advocating that state-owned enterprises spearhead core technology research and development, while private enterprises promote scenario-based applications (Liu et al., 2022) [6]. Power design enterprises are urged to incorporate carbon footprint management into the R&D process, yet high R&D costs and delayed returns impede technology promotion (Xiong et al., 2023) [7]. Insufficient collaboration among government, industry, academia, and research institutions, alongside weak international competitiveness, are identified as key shortcomings, necessitating addressal through carbon financial tools and policy linkages (Li et al., 2022)[8].
3. Innovation Mechanism and Market-Oriented Transformation of State-Owned Enterprises: It is suggested that, under the new national system, the State Energy Group must balance government guidance and market autonomy by concentrating resources to tackle "bottleneck" technologies (Dong, 2024) [9]. In terms of incentives, market-based measures such as equity incentives should be introduced to invigorate innovation momentum. However, the contradiction between administrative intervention and market flexibility within the current system remains unresolved (Yu, 2024) [10].
4. Technological Innovation and New Quality Productivity: Some scholars have integrated technological innovation with new quality productivity, emphasizing the reconuration of the innovation ecosystem driven by new quality productivity. They propose that new quality productivity necessitates power grid enterprises to be customer-demand driven and integrate technologies such as big data and artificial intelligence to form a dynamic innovation ecosystem (Yang et al., 2025) [11]. The improvement of the national innovation system hinges on policy coordination and market incentives, with the government guiding enterprises towards green technology transitions through tools like carbon trading (Fan, 2025) [12]. Nonetheless, existing research inadequately explores the regional adaptability of new quality productivity, and how to devise differentiated paths in alignment with provincial resource endowments requires further elaboration.

In summary, while existing literature provides rich insights into various dimensions of technological innovation in provincial power grid enterprises, it remains fragmented, largely focusing on single dimensions. A systematic framework and operational measures still need refinement. Therefore, building upon existing research results and theoretical foundations, combined with regional practices, this paper proposes a scientific and technological innovation system aimed at achieving "four highs" to propel the high-quality development of provincial power grid enterprises.

3 Theoretical Framework and Mathematical Modeling

According to the innovation ecosystem theory, innovation is not an isolated act of a single entity but rather a complex network system formed through the dynamic interaction of multiple participants. Consequently, scientific and technological innovation relies on an open and collaborative ecosystem.

Based on this theory, provincial power grid enterprises should construct a "dual circulation" ecosystem. On one hand, they should optimize internal circulation by effectively arranging research institutions within enterprises and strengthening vertical coordination between provincial and municipal companies. On the other hand, they should reinforce external circulation by uniting universities, research institutes, and enterprises within the industrial chain to establish an innovation consortium encompassing industry, university, research, and application.

We utilize a complex adaptive system model to further elucidate the pivotal role of establishing a scientific and technological innovation system in fostering innovation. Assuming there are N innovation entities within the system, with each entity i having an innovation level $I_i(t)$ at time t, the dynamic change can be described by the following equation:

$$\frac{dI_i(t)}{dt} = -kI_i(t) + \beta \sum_{j=1}^{N} A_{ij}(t)\, I_j(t) + \varepsilon_i(t) \tag{1}$$

Where k represents the natural decay rate of knowledge or the rate at which technology becomes obsolete; β is the coefficient of cooperation spillover; $A_{ij}(t)$is the adjacency matrix element, equaling 1 if entity i cooperates with entity j and 0 otherwise; and $\varepsilon_i(t)$ denotes the independent innovation of entity i.

From equation (1), it is evident that when an enterprise establishes a scientific and technological innovation system and strengthens internal and external circulation, it can enhance the level of innovation by increasing the value of cooperation spillover $\beta \sum_{j=1}^{N} A_{ij}(t)\, I_j(t)$. Furthermore, the probability of cooperation (network connection) among entities is given by:

$$p_{ij}(t) = \frac{1}{1+e^{-\gamma(I_i(t)+I_j(t)-C)}} \tag{2}$$

Where γ represents the network connection sensitivity, and C is the cooperation cost. Assuming all entities are uniformly connected with an average connection degree d, equation (1) can be simplified to the average field equation:

$$\frac{dI}{dt} = -kI + \beta dI + \mu \tag{3}$$

Solving for the steady-state level of innovation yields:

$$I^* = \frac{\mu}{k-\beta d} \tag{4}$$

The critical point is found at: $d_c = \frac{k}{\beta}$.

At this juncture, the enterprise's scientific and technological innovation system facilitates enhanced connectivity with external entities, thereby promoting an elevation in the level of scientific and technological innovation.

4 Strategic Framework and Implementation Measures

Building upon existing research outcomes and theoretical foundations, we propose ideas for constructing the scientific and technological innovation system from the three hierarchical levels of "goals - principles - measures". In the process of constructing the scientific and technological innovation system, provincial power grid enterprises should aspire to be "in the first echelon of State Grid and a world-class enterprise," endeavoring to create a scientific and technological innovation system characterized by "four highs". First, high strength in scientific research and technological breakthroughs. Focus on key areas such as the new power system, solve practical problems and break through the "no man's land" of technology. The second is high efficiency in scientific research management. Coordinating resources and optimizing processes to ensure efficient output of research activities. Third, there is a high level of scientific and technological talent. The implementation of the "Ten-Hundred-Thousand" program, the improvement of incentive mechanisms, and the cultivation of a high level talent pool. Fourth, the efficiency of technology transfer is high. We will strengthen the verification and demonstration projects of achievements, open up channels for transformation, and promote cross-field applications.

4.1 Promote the supply of high-quality technology

(1) Strengthen the functional positioning of research subjects. On the one hand, provincial electric power research institutes will focus on the development of common technologies, tackle common problems such as the stability of new energy grid connection and the optimization of energy storage systems, and build a provincial technical standard system. On the other hand, municipal companies should make differentiated layouts of laboratories in accordance with local resource endowments and industrial demands.

(2) Optimize the cross-disciplinary layout. In addition to traditional electrical engineering, we can add extended disciplines, systematically introduce disciplines such as artificial intelligence (AI), materials science, and digital twins, establish "energy information interdisciplinary research institutes", cultivate interdisciplinary innovation

teams, and promote joint efforts between university research teams and enterprise technical backbones through the "discipline leader + industry mentor" dual appointment system. To address the technical bottlenecks of interdisciplinary research.

(3) Promote the physical operation of the laboratory. Implement task-based assessment and decentralization of autonomy, adopt a "task-oriented, goal-based assessment" model, and give laboratory directors decision-making power on technical routes and allocation of funds. At the same time, establish a laboratory equipment sharing platform to achieve open sharing of resources, and give priority to opening up experimental resources to upstream and downstream enterprises in the industrial chain to promote seamless connection between technology verification and industrial application.

4.2 Deepen the integration of science and technology with the industry

(1) Build collaborative innovation consortia. Establish a joint office for research and industry, where technical experts from research institutions and market personnel from industrial units jointly move in to be responsible for demand matching, project incubation and intellectual property allocation. We will promote a flexible talent mobility mechanism and implement a "resident researcher" system. Researchers will bring their achievements to industrial units to participate in pilot production, retain their original units' positions and enjoy a share of the conversion benefits to solve the problem of "disconnection between research and application".

(2) Improve the ecosystem of the mass entrepreneurship and innovation platform. Strengthen the construction of the provincial "1+N" innovation and entrepreneurship centers, with the provincial centers coordinating resources and focusing on the incubation of major achievements; The municipal sub-centers will pilot market-oriented operations and explore the "technology equity + venture capital" model. At the same time, improve the full-chain service for technology transfer, establish a three-level incubation system of "concept validation - pilot scale-up - industrial landing", and support professional legal and financial teams to reduce the risk of technology commercialization.

(3) Establish a post-evaluation and feedback mechanism. Conduct a 3-5 year retrospective assessment of major achievements in terms of both economic and social benefits, quantitatively analyze indicators such as reducing grid losses and increasing the consumption rate of new energy, and incorporate the results into team performance evaluations.

4.3 Optimize the scientific research management system

(1) Implement process reengineering categorically. We will advance the reform of the "lump-sum system" for basic research, simplify the approval process for project initiation, and allow research teams to adjust the direction of fund usage independently, only requiring the submission of annual progress reports. Strengthen the market orientation mechanism for product development and introduce the "product manager responsibility system", where the Marketing Department gets involved in the research and development process in advance, defines technical parameters based on user needs in reverse, and ensures that the results are precisely matched with market demands.

(2) Deepen the reform of fund management. First, the proportion of indirect expenses will be adjusted dynamically. The upper limit of indirect expenses for basic research projects will be raised to support the long-term capacity building of the team. For product development projects, a “commercialization commission pool” will be set up to support subsequent research and development in proportion to sales. Second, implement backtracking incentives and risk hedging, and offer "backtracking rewards" for disruptive technological achievements, with additional bonuses if they still generate benefits after ten years; Establish a "research risk fund" to provide partial cost compensation for projects that fail due to policy changes.

(3) Fine-grained management of key nodes. The technical feasibility will be evaluated at different levels. A “red, yellow and green” review mechanism will be set up in the pre-research, pilot production and mass production stages. Projects that fail the technical feasibility verification will be terminated or transformed in a timely manner. At the same time, third-party institutions will be introduced to assess the market value of research results, and priority support will be given to projects with complete patent layout and high industrial chain synergy.

4.4 Strengthen talent incentives

(1) Implement differentiated and categorized incentive strategies. For basic researchers, a system of “rank promotion + academic influence points” will be implemented. Publishing papers in top journals or leading international standards will accelerate promotion. Establish the “Ten Years to Sharpen One Sword” long-term contribution award, and give millions of dollars in rewards to teams that overcome major theoretical problems. For application developers, a “profit-sharing + bet agreement” will be implemented. The team will commit to industrializing the achievement within three years and will be entitled to a 5%-10% share of the net profit after reaching the target. If the target is not met, promotion will be postponed but the opportunity to continue will be retained.

(2) Establish a dual-track career development system. On the one hand, promote the integration of technical and management sequences, allowing technical experts to retain their original title benefits after transferring to management positions, and requiring experience in leading major scientific and technological projects for positions of deputy chief engineer and above. On the other hand, young talents who meet the requirements will be appointed exceptionally. The position of “Young Chief Scientist” will be established, and those with doctoral degrees under the age of 40 will be directly appointed as senior scientists without the associate senior title, and they will be given the authority to independently form teams and allocate millions of funds.

(3) Foster an inclusive innovation ecosystem. Implement an innovation tolerance and burden reduction mechanism, make it clear that no responsibility will be held for failed projects that are “not intentional + procedural compliance”, and the related investment will be included in the enterprise’s research and development expenses; Implement the “research assistant system”, assign administrative assistants to key personnel, and reduce administrative tasks such as report filling.

A critical barrier to innovation in established organizations like provincial grid companies is the siloed nature of departments and disciplines. To effectively foster interdisciplinary collaboration, specific, actionable mechanisms are required:

(1) Establish Flexible Project Teams: For major R&D initiatives or demonstration projects, create temporary, mission-oriented teams drawing members from across technical, dispatch, marketing, and IT departments. Grant these teams significant autonomy over budgets and technical approaches, led by a dedicated project manager, mirroring the “agile team” model common in tech.

(2) Create Innovation Incubators: Set up physical or virtual incubator hubs to collect grassroots ideas and facilitate cross-departmental review. Promising ideas receive seed funding, mentorship, and dedicated space, allowing employees from different units to collaborate part-time or full-time, providing a sanctioned outlet for bottom-up innovation.

(3) Revamp Performance Metrics and Incentives: Integrate “cross-departmental collaboration contribution” into KPIs. Reward teams that successfully deliver interdisciplinary projects with significant bonuses, ensuring fair distribution among all contributors, thereby making collaboration a recognized and valued activity.

(4) Facilitate Informal Interaction: Organize regular tech talks, hackathons, and internal showcases to create informal networking opportunities. This builds the social capital and trust necessary for effective formal collaboration, breaking down communication barriers.

5 Conclusions and Recommendations

Drawing upon existing research and integrating practical experiences from provincial power grids such as State Grid Hubei Electric Power, this paper adheres to a goal-oriented and problem-oriented approach, anchoring the objective of being "in the first echelon of State Grid and a world-class enterprise. It focuses on the high-quality construction of the scientific and technological innovation system, fully leveraging the three pivotal roles of scientific and technological innovation, industrial control, and security support. By allocating innovation resources and constructing operational mechanisms, it forms an organized scientific research model of "independent operation and joint efforts," building a corporate scientific and technological innovation system characterized by "four highs. This system promotes high-quality scientific and technological supply, deepens the integration of science, technology, and industry, optimizes and enhances the scientific research management system, strengthens the cultivation and incentive of scientific and technological talents, and robustly supports enterprises in establishing a power scientific and technological innovation highland with core competitiveness.

The successful implementation of this “Four-High” system promises significant long-term benefits that extend beyond the individual enterprise. For the enterprises themselves, it builds sustainable competitive advantage and adaptability in a rapidly changing energy landscape. For the broader energy sector, it accelerates the deployment of critical technologies and business models, directly supporting the construction of a resilient and clean new power system. At a national level, it contributes substantially to achieving "dual carbon" goals, enhancing energy security, and positioning China as a global leader in energy technology.

To ensure the high-quality development of the scientific and technological innovation system, the following safeguard measures are recommended:

- Improve the Stable Investment Mechanism: Conduct regular assessments and tracking to ensure sustained funding support.
- Strengthen Organizational System Guarantees: Optimize decision-making mechanisms and enhance professional management capabilities.
- Create a Favorable Innovation Environment: Foster an innovation culture, encourage collaborative innovation, and promote win-win cooperation.

References

1. Trinh L, Adam B. 2016. The Impact of R&D Subsidy on Innovation: Evidence from New Zealand Firms. Economics of Innovation & New Technology 5(2016): 429–452.
2. Bronzini R, Piselli P. 2016. The impact of R&D subsidies on firm innovation. Research Policy 45,02(2016): 442–457.
3. Jing Yang, Jianjun Tuo, and Shaohui Wang. 2018. Research on the Construction of Regional Collaborative Scientific and Technological Innovation System of Provincial Economic Research Institutes. Science and Technology Innovation and Application 2 (2018), 37–39.
4. Junhong Duan, Wenxi Zhen, Changming Xia, et al. 2024. Research on Evaluation Index System of Scientific and Technological Innovation Capacity of Power Grid Enterprises Based on AHP. Rural Electricity Management 2 (2024), 54–56.
5. Yijun Fei, Jian Du, and Zhanlong Zhang. 2024. Research on the Whole-Process Support System for Scientific and Technological Innovation Oriented to the New Power System. Jiangsu Science and Technology Information 41, 1 (2024), 7–11+26.
6. Renhou Liu, Yang Yang, Minglei Ding, et al. 2022. Research on the Construction and Innovation Path of China's Green and Low-Carbon Technology System under the "Dual Carbon" Goals. Guangxi Social Sciences 4 (2022), 8–15.
7. Wenqing Xiong, Zhijun Bai, Yimin Han, et al. 2023. Challenges and Strategies for Carbon Footprint Management in Power Design Enterprises. Electric Power Survey & Design 4 (2023), 24–29.
8. Youhuan Li and Songtao Shou. 2022. Research on the Problems and Paths of China's Current Science and Technology Innovation in Supporting the "Dual Carbon" Goals. Science & Technology & Finance 5 (2022), 15–24.
9. Binqi Dong. 2024. Research on Scientific and Technological Innovation Countermeasures of National Energy Group under the New National System. Energy Science and Technology 22, 5 (2024), 3–7+21.
10. Lei Yu. 2024. Research on the Construction of Science and Technology Innovation System in State-Owned Energy Enterprises. Strait Science and Technology & Industry 37, 6 (2024), 70–72.
11. Tong Yang, Tianyi Zhang, and Ru Liu. 2025. Practice of Science and Technology Innovation Ecosystem for Power Grid Enterprises Based on New Quality Productivity. General Standardization 4 (2025), 52–54.

12. Chunliang Fan. 2025. The Prospect of China's Science and Technology Innovation and Its Implications for Global Development from the Perspective of New Quality Productivity. Contemporary China and the World 1 (2025), 65–78.