

The "Five-Dimensional Integration" Model of Power Supply Enterprises Empowered by Digital Technology Services

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Abstract: The digital wave is sweeping through the traditional energy industry with unprecedented momentum. As a critical hub connecting energy and users, power supply enterprises urgently need to restructure their management and service models. The "Five-Dimensional Integration" model, as an in-depth exploration under digital transformation, breaks through the limitations of fragmented business units and isolated data silos. It establishes a multi-dimensional framework with synergy across five core dimensions: customer, equipment, operation & maintenance, dispatch, and safety. Supported by digital twin technology, AI algorithms, and the Internet of Things, this model significantly enhances power grid transparency, responsiveness to faults, and proactiveness in customer services. In practice, "Five-Dimensional Integration" goes beyond the simple integration of tools—it is a fundamental shift in mechanisms and thinking, providing strong strategic momentum and support for high-quality development in power supply enterprises.

1. Introduction

As an essential part of the national energy system, the operational efficiency and management level of power supply enterprises directly affect the quality of socio-economic development. With the deepening wave of digitalization, the traditional power supply model—mainly driven by manual management and single-dimensional operations—has reached a bottleneck, with issues such as data silos, delayed responses, and high costs becoming increasingly prominent. The "Five-Dimensional Integration" model integrates five key modules: customer service, equipment management, operation & maintenance, dispatch control, and safety assurance. It provides a new path for power enterprises to build unified platforms, break information barriers, and achieve intelligent decision-making. This paper combines practical operational cases to systematically explore the implementation path and core technologies of the "Five-Dimensional Integration" model, aiming to offer reference and insights for relevant enterprises.

2. Transformation Needs of Power Supply Enterprises under Digital Empowerment

2.1 Constraints in Traditional Power Supply Systems

Most existing power supply enterprises still rely on siloed business systems, with evident inter-departmental barriers, fragmented data, and outdated updates. There is a lack of effective data integration and sharing mechanisms. Equipment operation and maintenance still largely depend on periodic inspections, lacking real-time monitoring and fault prediction capabilities—often leading to slow response, low visibility, and inadequate control. In customer service, responses are mainly manually scheduled, resulting in long handling chains, slow feedback, and low satisfaction, significantly limiting the overall service level. More critically, in response to power accidents or extreme weather events, traditional systems often suffer from slow emergency response, weak collaboration, and a decision-making pace that lags behind risk propagation, compromising power supply reliability^[1].

2.2 The Forcing Mechanism of Digital Development on Power Enterprises

The energy industry is undergoing a transformative phase of deep integration, where power systems must ensure not only safety and stability but also progress in refined management, proactive services, and green, low-carbon development. With the advancement of national strategies such as "Digital China" and "Dual Carbon Goals," power enterprises can no longer stop at equipment upgrades but must move toward systemic reconstruction and value chain optimization. Customers now expect "invisible electricity use" and "second-level response" as the new service benchmarks. Grid operations must transition from "reading blueprints" to "viewing digital models," from "experience-based decisions" to "algorithm-driven actions." In this context, digital technologies have shifted from optional add-ons to essential engines, compelling enterprises to break conventional mindsets and build resilient, self-learning intelligent power systems.

3. Architecture and Core Logic of the "Five-Dimensional Integration" Model

3.1 Concept and Functional Positioning of the Five Dimensions

"Five-Dimensional Integration" is a unified operational model driven by digital technology and centered on business collaboration. It aims to break through the limitations of "segmented management and isolated operation" in traditional power supply enterprises. Its core framework revolves around five major dimensions: customer service, equipment management, operation & maintenance, dispatch control, and safety assurance, thereby forming a horizontally interconnected, vertically penetrative, data-driven operational loop.

The Customer Dimension focuses on electricity usage experience and proactive service response.

The Equipment Dimension builds a full-lifecycle digital twin system.

The Operation & Maintenance Dimension promotes a task loop that integrates human and technological efforts.

The Dispatch Dimension enables refined load allocation and responsive mechanisms.

The Safety Dimension provides dynamic risk identification and control systems throughout grid operation.

These five dimensions support and embed into each other, together forming a highly coupled, perceptive, and collaborative intelligent operation system.

3.2 Coordination and Data Linkage Mechanism Across Dimensions

The five dimensions are not merely stitched-together modules, but components of a logically closed-loop system enabled by a unified digital platform.

Customer feedback data is instantly transmitted to the dispatch system, dynamically adjusting operation & maintenance plans.

Abnormal equipment states automatically trigger the safety module's early warning, which then links with dispatch to execute power rerouting strategies.

Maintenance personnel upload their task results to the equipment archive system in real time, supporting future precise repairs and lifecycle management.

Dispatch analysis of load fluctuations can feed back to the customer service front-end for early notifications and energy efficiency guidance.

The entire system is built upon a "one central platform + five front-end modules" structure. With a highly efficient data linkage mechanism, it connects front-end sensing with back-end decision-making, achieving full-chain data flow with features like "single-source data sharing, unified business processing, and one-click decision execution."

3.3 Intelligent Evolution of the Integrated Operational Logic

In practical applications, "Five-Dimensional Integration" not only reshapes business processes but also endows power supply systems with adaptive and self-evolving capabilities^[2].

The system uses deep learning models to continuously ingest data from past incidents, user behavior patterns, and equipment status changes, autonomously training and optimizing its strategy library.

The future direction points to a hybrid model of "system intelligence coordination + human-machine joint decision-making," where routine operations are handled autonomously by the system, while critical or complex events involve human judgment, creating a synergy between intelligence and experience.

With the integration of 5G, edge computing, and distributed energy resources, this architecture will demonstrate greater flexibility and adaptability in regional power supply scenarios, ultimately empowering the grid with a true "smart nervous system."

4. Construction of the Digital Technology Support System

4.1 Foundational Guarantee of Data Acquisition and Integration Technologies

To build a "Five-Dimensional Integration" model, the foundation lies in accurate sensing, real-time updates, and seamless data fusion. Power supply enterprises deploy high-precision IoT sensors at key nodes—such as substations, cable joints, distribution boxes, and user terminals—enabling second-level collection of multi-dimensional information like voltage, current, temperature, humidity, and load fluctuations.

Edge computing gateways are used to preprocess data on-site, easing the burden on central systems and enhancing real-time responsiveness. At the data aggregation layer, a unified data interface and standardized formats are established to integrate customer systems, dispatch platforms, safety monitoring platforms, and maintenance terminals into a unified data lake architecture. This horizontal and vertical integration provides a solid foundation for future analysis and modeling^[3].

4.2 Model Support from Intelligent Analysis and Predictive Algorithms

Data alone does not equate to insight. The true value lies in the ability to enable intelligent, data-driven decision-making. Power supply enterprises have developed AI-based algorithm libraries tailored to specific business scenarios.

For predictive maintenance, deep neural networks are trained on historical failure-tagged datasets to identify potential abnormal nodes early, shifting the paradigm from reactive repairs to preventive risk control.

In user-side load management, Long Short-Term Memory (LSTM) networks model power consumption habits to guide dispatch systems in implementing peak-shaving and load-reduction strategies.

These algorithmic models are not stand-alone—they are embedded throughout business process nodes. They learn dynamically and undergo iterative optimization, forming a closed-loop chain of "sensing → judgment → response → re-sensing," enabling the system to mimic brain-like reasoning capabilities.

4.3 System Coordination between Platform Support and Terminal Devices

In real-world operations, the quality of "Five-Dimensional Integration" depends largely on the efficient collaboration between platforms and terminals.

Power enterprises have built unified digital operation platforms integrating customer service interfaces, equipment asset management, dispatch visualization, and safety alert modules—with unified entry points and centralized access control.

Field personnel are equipped with intelligent handheld terminals or AR-assisted glasses, allowing them to receive tasks, navigate inspection paths, and upload repair results in real-time, greatly reducing manual recording errors and communication costs.

The platform provides holographic data storage, building traceable task histories and event replay systems to support supervision, fault analysis, and continuous mechanism optimization. The platform is not merely a tool—it serves as the central nervous system connecting people, equipment, processes, and services.

5. Practical Pathways and Typical Application Scenarios of "Five-Dimensional Integration"

5.1 Digital Reshaping of the Customer Service Dimension

Customer interaction is the first touchpoint of power supply services. In the implementation of the "Five-Dimensional Integration" model, many regional power companies have restructured their customer service systems. An integrated service platform has been built, covering mobile apps, self-service terminals, the 95598 hotline, and official WeChat accounts. Users can perform repairs, payments, complaints, and suggestions all through one-click access^[4].

AI-based intelligent customer service systems replace human agents during peak hours, automatically identifying issue types and routing them accurately—common queries can receive responses within seconds. In some areas, integration with customer-side smart devices—such as home energy storage systems and distributed photovoltaics—has been piloted. These systems monitor power usage in real time, provide alerts on price trends, and offer energy efficiency optimization suggestions.

Such transformation effectively shifts the paradigm from a passive, problem-driven service model to a "data-informed, service-preemptive" user experience upgrade.

5.2 Closed-Loop Integration of Equipment Management and Maintenance Systems

On the equipment side, power enterprises have generally established digital archives covering the full lifecycle of devices—from procurement, installation, commissioning, operational status, maintenance records, to retirement. Each phase is supported by data and labeled for traceability, creating clear "portraits" of each device.

The operation and maintenance (O&M) system relies on an intelligent work order platform to enable precise task dispatching. For instance, in a city-level company in a certain province, the system automatically generates inspection priorities based on equipment status ratings and risk indices. Field staff receive their tasks with navigational guidance, complete tasks with photo and voice uploads via mobile terminals, and the equipment database updates automatically.

Remote intelligent comparison systems handle O&M quality checks, reducing omission rates by over 70% and significantly lowering manual inspection costs. Sudden equipment failures trigger real-time alerts to dispatch and safety modules, promoting cross-department collaboration in emergency handling.

5.3 Integrated Response of Safety and Dispatch Systems

The dispatch system is no longer an isolated information island—it functions as the central nerve of the "Five-Dimensional Integration" framework. The dispatch platform integrates grid operation monitoring, load forecasting, energy flow distribution, contingency planning, and fault simulation, enabling minute-level adjustments and visualized decision-making^[5].

When electricity demand surges or distributed power experiences unexpected fluctuations, the platform can automatically activate regional resources and engage load-side response mechanisms to quickly balance loads and prevent large-scale disruptions. The safety module, embedded within the system, includes multi-level early warning mechanisms to detect signals such as cable overheating, voltage anomalies, and switch tripping. It can issue accident alerts up to 30 minutes in advance, allowing the dispatch system to optimize grid topology or execute isolation commands.

In one case study, during a typhoon-induced short circuit event, a regional power bureau used the system to locate the fault and restore supply in under two minutes—dramatically improving grid resilience and risk response capabilities.

6. Strategic Recommendations and Safeguard Mechanisms for Advancing "Five-Dimensional Integration"

6.1 Strengthening Organizational Coordination and Top-Level Design

The "Five-Dimensional Integration" model imposes higher requirements on organizational structure and management mechanisms. It is not merely a system deployment project, but a profound reconstruction of management models.

First, enterprises should establish dedicated leadership groups and promotion offices at the corporate level to coordinate across departments including customer service, dispatch, operations, safety supervision, and IT. This helps to break habitual "silo thinking."

Second, it is necessary to build a unified platform, standardized data systems, and clearly defined permissions. The focus should shift from "department-led" to "platform-coordinated" operations.

Using "task chains" as the logical backbone, fragmented workflows can be restructured into traceable, quantifiable closed loops, achieving governance transformation from "post-reporting" to "process-linked" management.

6.2 Enhancing Talent Development and Technical Capabilities

The success of technical systems depends fundamentally on people. Power supply enterprises should formulate specialized talent development plans for key positions related to data acquisition, system development, algorithm analysis, and platform maintenance, bridging the skill gap between electrical expertise and digital technology.

A dual model of "training + hands-on practice" is recommended: organizing cross-disciplinary competitions, collaborative problem-solving teams, and case study reviews to refine employees' digital literacy and operational skills.

Traditional technical personnel should be encouraged to transition into "digital electricians," gaining the ability to interpret data, analyze visualizations, and make system adjustments through digital platforms.

At the same time, companies should actively connect with universities, research institutes, and tech firms to bring in interdisciplinary talents in AI, IoT, and big data, forming a diverse talent pool through a combination of internal training and external recruitment.

6.3 Establishing a Continuously Optimized Operational Evaluation System

Even the most advanced systems require scientific evaluation mechanisms for sustained optimization. It is recommended that power enterprises establish a multi-dimensional KPI system covering the five key areas—such as customer satisfaction, equipment health index, task closure rate, dispatch response time, and safety risk levels—and implement dynamic monitoring and quarterly evaluations.

Operational data from the platform should feed back to decision-making levels in real time. A dual-trigger mechanism based on "data + events" can prompt intelligent adjustments. For example, when complaint rates in a particular region remain high, the system can compare fault frequencies with dispatch response records and provide automated improvement suggestions^[6].

Additionally, performance outcomes should be tightly linked to rewards and accountability systems, aligning evaluation results with performance appraisals. This will ensure cross-dimensional goal alignment and efficient resource allocation.

7. Conclusion

Digital technologies are rapidly redefining the boundaries and value logic of power supply enterprises. The "Five-Dimensional Integration" model is not merely a systemic process innovation; it represents a forward-looking approach to organizational evolution.

By leveraging a unified platform to support diversified business dimensions, and replacing rigid procedures with dynamic coordination mechanisms, grid management is transforming—from linear to networked, from reactive to proactive, and from delayed to predictive. In this transformation journey, technology serves as the fuel, mechanisms as the engine, while organizational intent and talent ecosystems are the true driving forces of deep change.

Only by refining mechanisms through real-world practice and tempering systems through practical challenges can power enterprises advance from basic digitalization to intelligent transformation—ultimately building a modern energy service system characterized by resilience, agility, and foresight.

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