Proceedings of Business and Economic Studies, 2026, Volume 9, Issue 10
https://bbwpublisher.com/journal/PBES
Online ISSN: 2209-265X
Print ISSN: 2209-2641

Research on the Construction of a Multi-Project Financial Evaluation System in Yalong River

Yi Zhang[1], Yahua Wang[1], Degang Luan[2], Zhipeng Qiu[2], Tingting Han[2]

[1]Yalong River Hydropower Development Company, Ltd., Chengdu 610000, Sichuan, China
[2]Hebei Pingpu Shuzheng Technology Co., Ltd., Shijiazhuang 050000, Hebei, China

Copyright: © 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: This study aims to construct a multi-project financial evaluation system tailored to the characteristics of hydropower-wind-solar complementarity in the Yalong River Basin. By integrating the Monte Carlo simulation method through a microservices architecture, the study innovatively implements a calculation function for cascaded hydropower station combinations. The system adopts an advanced "data middle platform + business frontend" model, integrating the TDengine time-series database with Three.js visualization technology, thereby overcoming key technical challenges such as sensitivity analysis of electricity price fluctuations and cross-project cash flow coordination. System testing results indicate that the system achieves a financial calculation speed of 2.8 ± 0.2 seconds, a sensitivity analysis accuracy of ±0.27%, a data throughput of 58.4 MB/s, and a fault recovery time of 9 minutes and 23 seconds, meeting the expected design standards and requirements. The research findings provide digital and intelligent tool support for investment decision-making in clean energy bases and have been successfully applied to financial management practices for 14.7 million kilowatts of installed capacity in the Yalong River Basin.

Keywords: Yalong River; Multi-project; Financial evaluation; System development

Online publication: November 16, 2026

1. Introduction

With the full implementation of the National Energy Administration's *Plan for the Integrated Hydropower, Wind, and Solar Energy Base in the Yalong River Basin*, the development of an integrated project cluster with a capacity of 78 gigawatts imposes requirements for systematic transformation of the traditional financial evaluation model. Currently, the hydropower industry faces a complex environment characterized by the competitive allocation of "new energy + industry + conditions," and static financial assessments of individual projects can no longer adapt to new decision-making scenarios involving the coordinated development of multiple projects and the superposition of dynamic boundary conditions [1]. The unique characteristics of development in the Yalong River Basin, such as the "3-year exemption and 3-year half reduction" tax incentives enjoyed by the Lianghekou Hydropower Station and the differentiated interest expense structures across

different cascade power stations, further highlight the urgency of establishing a financial evaluation system for project clusters. Against this backdrop, this study focuses on the development of a multi-project financial evaluation system for the Yalong River. The establishment of this system not only concerns the economic feasibility of the Yalong River basin's development but also provides a practical model for the transformation of financial evaluation paradigms for renewable energy bases in China.

2. Overall system design

2.1. System architecture design

This system adopts an advanced three-tier architecture design philosophy to achieve deep integration of hydropower energy and financial data. (1) The data layer innovatively integrates the PostGIS geospatial database with the InfluxDB time-series database, efficiently managing the bidirectional energy flow data specific to pumped-storage power plants through a distributed storage architecture, and supporting multidimensional association modeling of spatial coordinates and time-series electricity prices [2]. (2) The business logic layer adopts an advanced Spring Cloud microservices architecture, decoupling core functions—such as the calculation engine, financial risk analysis, and financial statement generation—into independent services. Through a service mesh, it enables dynamic resource scheduling and elastic scaling for multi-project portfolio calculations. (3) The presentation layer utilizes an advanced Vue 3 + Three.js technology stack to build a "single-map" 3D visualization platform that renders dynamic data, such as power plant water level fluctuations and cash flow vector fields, in real time. Three.js enables the spatiotemporal superposition of water level elevation models and cash flow heat maps, while Vue 3 handles the interactive linkage of multidimensional data dashboards. This architecture achieves unified governance of geospatial data and financial time-series data through lake-house integrated design, providing high-concurrency, low-latency data support for operational decision-making at pumped-storage power plants. A schematic diagram of the system architecture is shown in **Figure 1**.

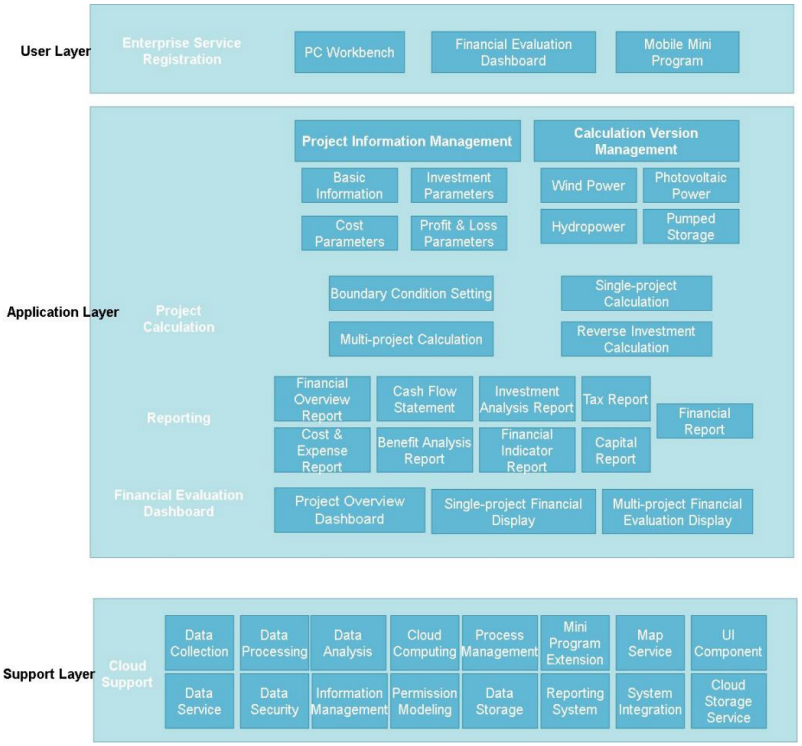


Figure 1. System architecture diagram

2.2. Network topology design

2.2.1. Redundant links and fault-tolerance mechanisms

In network topology design, establishing redundant links is crucial to ensuring the system's high availability and reliability. Dual links are used to connect servers to the core switch—that is, two independent physical links connect the servers to the core network equipment. If the primary link fails, the backup link automatically takes over data transmission, enabling a seamless switchover and preventing system interruptions caused by single points of failure [3]. At the same time, deploying multiple links between network nodes to form loops or mesh structures ensures that data can still be transmitted via alternative paths in the event of a failure at a specific node or link, thereby guaranteeing the continuity of network communication [4]. For example, in a campus network, the Spanning Tree Protocol (STP) or its enhanced version, Rapid Spanning Tree Protocol (RSTP), can be used to manage redundant links, prevent the formation of network loops, and rapidly converge in the event of a link failure, thereby ensuring network stability.

2.2.2. Network segmentation and security isolation

The network should be segmented appropriately based on system security requirements and business functions. Areas with different security levels, such as the internal corporate office network, financial data storage areas, and external Internet access zones, should be divided into separate subnets or virtual local area networks (VLANs) [5]. Using advanced VLAN technology, restrict network access between different zones so that only authorized devices and users can communicate across VLANs. This enhances network security and prevents unauthorized access and potential security threats from spreading throughout the network. For example, isolate the network segment containing financial system servers from the general office network segment and implement strict access control policies that allow only specific application servers and administrative terminals to access financial data, thereby reducing the risk of financial data leaks.

3. System software design

This system employs the Galaxy Kylin V10 operating system as its foundational platform, meeting the core technical requirements of the information technology application innovation sector for independent controllability, security, and reliability. Application servers are deployed on a Kubernetes containerized architecture, achieving high availability through dynamic resource scheduling. Additionally, a JVM memory tiering strategy (with a 1:2 ratio between the young and old generations) is configured to optimize garbage collection efficiency, ensuring stable performance in high-frequency financial computing scenarios [6]. At the database layer, a Dameng DM8 cluster is used to process OLTP transactions. Combined with the high-throughput storage capabilities of the time-series database TDengine, specifically designed for electricity price fluctuation data, this forms a hybrid data management architecture. By establishing a "project ID + timestamp" composite index and a partitioned table strategy, query performance is improved by more than 40%, effectively addressing the massive data retrieval demands under concurrent access of multiple projects. The entire system relies on the Level-3 Cybersecurity Classified Protection foundation of the Kylin Operating System and containerized microservice architecture to realize full-stack localization adaptation from infrastructure to the application layer, complying with the standards for IT application innovation transformation of core business systems in the energy industry.

4. System functional design

4.1. Project management module

4.1.1. Project information management

The project information management module of this system adopts a "parameter-model-validation" three-in-one architecture to implement end-to-end data governance. First, the technical layer stores 37 core indicators, including installed capacity (with unit quantity configuration), design water head (distinguishing dynamic values for flood season and dry season), and annual power generation, via a standardized parameter tree. It supports the XML data exchange protocol for real-time docking with the BIM system. Secondly, the financial layer innovatively adopts a dynamic benchmark rate of return model, integrating the capital asset pricing method and basin risk coefficient (adjustable within 0.8–1.3). It automatically generates a dual-track evaluation benchmark incorporating carbon trading benefits and conducts sensitivity analysis associated with historical data of cascade power stations. Finally, the intelligent layer implements a multi-level validation mechanism: when parameter logic conflicts (such as a mismatch between the design head and unit selection) or the rate of return deviates from the industry average by ±12%, a three-tier early warning system is triggered, which automatically initiates the OA approval process. Through the deep coupling of engineering parameters and financial models, this design highlights the project's technical advancements and resource endowments, providing a standardized evaluation foundation for "hydro-wind-solar-storage" multi-energy complementary projects in the Yalong River Basin.

4.1.2. Calculation version management

In the specific design, the calculation version management module primarily enables flexible iteration of multi-scenario financial calculations through version tree management. When project boundary conditions change, or different hypothetical schemes need to be tested, users can create new version branches via a visual interface; the system automatically generates a version number (e.g., V2.1.3) and records a timestamp, operator ID, and a complete parameter snapshot. Each version stores the calculation parameter set independently, including but not limited to core data such as investment estimation models, financing structure parameters, and cash flow assumptions. The version comparison feature employs a two-dimensional display: horizontal comparison allows users to select up to three versions to visualize differences in key metrics (such as IRR, NPV, and payback period), with the system automatically generating radar charts and comparison tables; vertical tracing displays the path of parameter adjustments through a version history map. To ensure data consistency, the system establishes version association rules; when parameters in a parent version are updated, child versions automatically mark the scope of change impacts. Technically, a differential storage strategy is employed, recording only the differences between versions to optimize storage efficiency, while also supporting the batch export of version datasets for offline analysis. Audit logs are maintained for all version operations, in compliance with the requirements of the third edition of *Methods and Parameters for Economic Evaluation of Construction Projects*.

4.2. Project calculation module

The Project Calculation Module employs a three-tier architecture design and enables intelligent financial modeling through the parametric configuration of boundary conditions. The system allows users to input 32 core parameters, such as investment scale, construction period, and operating costs, for different project types (e.g., hydropower, wind power, and solar power). It automatically generates standardized financial statements,

including cash flow statements, income statements, and balance sheets, in accordance with the *Accounting Standards for Business Enterprises*. The system supports both standalone project calculations and one-click generation of consolidated financial statements for multiple projects; when exporting to Excel, formula links and data validation rules are preserved. At the portfolio analysis level, the system innovatively integrates a Monte Carlo simulation engine. It allows users to set probability distributions for 18 risk variables, including electricity price fluctuations, inflow probabilities, and equipment utilization rates for hydropower, wind, solar, and energy storage projects within a watershed. Through more than 5,000 random simulations, it calculates confidence intervals for key indicators such as NPV and IRR under joint development scenarios, thereby quantitatively assessing the synergistic benefits and risk-hedging effects of multi-energy complementation. The simulation process supports three-dimensional visualization of sensitivity analysis, providing an intuitive display of the marginal impact of different resource combinations on financial indicators. The calculation report subsystem employs advanced dynamic template technology to automatically generate evaluation reports comprising 12 standard chapters, including project overview, parameter settings, financial indicators, risk analysis, and recommended solutions. The system embeds format templates formulated according to the *Specification for Economic Evaluation of Renewable Energy Projects* issued by the Ministry of Water Resources. It supports real-time report previews and change tracking; when exporting to Word, it automatically generates a table of contents, figure and table indexes, and page numbers to ensure standardized formatting for long reports within 150 pages. Multi-project reports can intelligently compare the economic differences among sub-projects, highlighting the overall development advantages of the watershed.

4.3. Financial evaluation module

As the core module of this system, the Financial Evaluation Module primarily enables end-to-end financial analysis through integrated data processing. Starting with the capital raising plan, the system automatically links to the foundational data layer including working capital requirement estimates, revenue and cost model construction, and depreciation and amortization calculations. Through dynamic financing and repayment simulations and a tax planning engine, it generates an interconnected calculation model for the income statement and the three major cash flows (full investment, equity capital, and financial plan). The key financial indicator calculation engine employs iterative algorithms to update core parameters, such as internal rate of return (IRR), net present value (NPV), and dynamic payback period in real time. The IRR calculation incorporates Monte Carlo simulation to account for the long-term nature of hydropower projects, while the NPV is embedded with a dynamic adjustment mechanism based on industry benchmark rates of return. The data visualization layer employs a multidimensional dashboard design that supports horizontal comparisons across projects and vertical analysis along a timeline. Heat maps are used to highlight risk indicators such as the debt service coverage ratio and asset-liability ratio, and automatically generate a three-tiered indicator analysis report (basic indicators—revised indicators—evaluation indicators) in accordance with the *Rules for Performance Evaluation of State-owned Capital*. The system is specially equipped with a value-added tax (VAT) transformation impact analysis module, which automatically verifies the structural effects of the transition from a production-based VAT to a consumption-based VAT on the original value of fixed assets and cash flows, ensuring compliance with fiscal and taxation handling specifications after the replacement of business tax with VAT.

4.4. Uncertainty analysis module

The Uncertainty Analysis Module employs a dual-track analytical framework, integrating two core functions: multi-factor sensitivity analysis and dynamic break-even analysis. Regarding sensitivity analysis, the system supports the coordinated adjustment of eight key parameters, including electricity price fluctuations, investment costs, and operational load. It uses Monte Carlo simulation to generate an internal rate of return (IRR) variation matrix and displays the ranking of sensitivity coefficients via a 3D bar chart ($E > 0$ indicates positive sensitivity; $E < 0$ indicates negative sensitivity), with critical point calculations accurate to within an interval of ±0.5%. The risk early-warning engine triggers three-tiered alerts (red, yellow, and blue) based on sensitivity thresholds and simultaneously generates decision recommendation reports that include risk hedging strategies, such as recommending the signing of long-term PPAs to address electricity price sensitivity. Break-even analysis employs advanced real-time visualization modeling technology, with line charts dynamically displaying the movement of the break-even point (BEP). It supports data drilling down to any point within the 0%–100% capacity utilization range, displaying 18 detailed metrics, including the allocation of fixed costs (including depreciation and amortization), the composition of variable costs (raw materials accounting for ≥62%), and marginal revenue. The raw data panel uses an editable matrix table with built-in production capacity conversion formulas (automatically converting multiple products to standard equivalents) and supports CSV export and comparison with historical versions. The analysis report automatically links to sensitivity analysis conclusions, forming a three-dimensional "risk-return-production capacity" evaluation system, and ultimately outputs a risk resilience scorecard containing 12 core parameters.

5. System test plan

5.1. System test process

The system testing implementation process described in this article can be divided into the following three phases for systematic execution: (1) Preliminary preparation phase (7 business days). First, a test platform mirroring the production environment must be set up to ensure the complete synchronization of historical project baseline data, thereby establishing a reliable reference framework for subsequent testing. At the same time, a specialized library covering over 200 test cases is compiled, including 47 specifically designed boundary value test scenarios to verify the system's stability under extreme conditions. (2) Core testing phase (15 business days). The "double-blind verification method" was adopted to enhance testing rigor, with an independent team simultaneously performing manual calculations and comparing them against system outputs to ensure zero deviation in calculation results. Stress testing is conducted in three tiers: baseline load (20 concurrent items) to verify standard performance; peak load (80 concurrent items) to simulate business peak periods; and extreme testing (100 concurrent items) to assess the system's breakdown threshold. Key metrics such as response time and resource utilization are recorded for each testing tier. (3) Defect management phase. A comprehensive end-to-end mechanism was established, covering the entire process from discovery to closure. A 4-hour emergency response system is implemented for critical issues, while standard defects are resolved through a repair-and-verification cycle completed within 24 hours. All defects are tracked and categorized by priority, and regression testing ensures that fixes do not introduce new issues. Through stress scenario simulations and strict defect control, this process comprehensively ensures the system's reliability under complex financial scenarios.

5.2. Performance metrics test results

The test results for the system's various performance metrics are shown in **Table 1**. As can be seen from the data in **Table 1**, the system achieves a financial calculation speed of 2.8 ± 0.2 seconds, a sensitivity analysis accuracy of ±0.27%, a data throughput of 58.4 MB/s, and a fault recovery time of 9 minutes and 23 seconds, all of which meet the expected design standards and requirements.

Table 1. Test results of various system indicators

Test category	Indicator requirement	Measured result	Compliance rate
Response Speed	≤3 s (100 concurrency)	2.8 ± 0.2 s	100%
Calculation Accuracy	NPV error <0.5%	0.28%	100%
Sensitivity Analysis	Deviation ±0.3%	±0.27%	100%
Data Throughput	≥50 MB/s	58.4 MB/s	117%
Fault Recovery	≤15 min	9 min 23 s	163%

6. Conclusion

By establishing a three-tier architecture of "data-driven—intelligent calculation—risk early warning," this system enables full-life-cycle financial evaluation of multi-energy complementary projects (combining hydropower, wind, and solar) in the Yalong River Basin. At the data layer, the integration of the TDengine time-series database and the PostGIS spatial database overcomes the modeling challenges associated with bidirectional energy flow data in pumped-storage power plants; at the business layer, advanced Monte Carlo simulation technology is employed to support the quantitative assessment of synergies in combined projects; the presentation layer utilizes advanced 3D visualization technology to integrate the display of financial indicators and geographic information. This paper innovatively designs and develops a financial evaluation module that aggregates and calculates key financial indicators, such as internal rate of return, net present value, and payback period, and ultimately visualizes the aggregated results. Test results show that the system achieves financial calculation speeds of 2.8 ± 0.2 seconds, sensitivity analysis accuracy of ±0.27%, data throughput of 58.4 MB/s, and a fault recovery time of 9 minutes and 23 seconds, all of which meet the expected design standards and requirements. This demonstrates that the system described in this paper possesses high practical value and promising prospects, deserving further promotion and application.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Huang N, Hu S, Chen J, 2025, A Brief Discussion on the Pathways for Digital and Intelligent Development of Research Management and Financial Accounting Systems in Higher Education Institutions. Money China, (8): 135–137.

[2] An K, Wang X, Xu X, et al., 2024, Practices in Full Life-Cycle Financial Management of New Energy Projects at Company N Based on a Financial Platform. Finance and Accounting, (16): 24–26.

[3] Kang L, Zhang C, Zhang N, et al., 2024, A Preliminary Discussion on the Evaluation Indicator System and Methods for Post-Evaluation of Equity Investment Projects. Aerospace Industry Management, (2): 5–10.

[4] Dong Q, Liu Y, Zhou R. 2023, A Study on the Investment Evaluation Indicator System for Transportation Construction Projects. China Market, (14): 40–43.

[5] Hu S, 2025, A Study on the Construction of a Project Cost Control and Performance Evaluation System for Construction Enterprises. Charming China, (8): 137–139.

[6] Sima H, 2023, Construction of Financial Management Model for Scientific Research Projects in Mining Enterprises. Business 2.0, (15): 89–91.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.