Construction of a User-Side Energy Storage Project Budget Estimation Classification System Based on the Intelligent Comprehensive Energy Planning Simulation Platform

Jing Zhou, Wei He, Tao Han and Jingcheng Zhang*

[1]Three Gorges Electric Energy Co., Ltd. Wuhan, Hubei, 430021, China

*Corresponding author's e-mail: zhang_jicheng@ctg.com.cn

Abstract. In view of the shortcomings of the traditional project budget estimation system in the context of the rapid development of user-side energy storage, this paper constructs a new project budget estimation classification system based on the intelligent integrated energy planning simulation platform. The new system takes into account the characteristics of the integrated battery system in the current market, and divides the battery system into three categories according to whether the converter and transformer need to be selected separately; The impact of the grid-connected voltage level on the project cost is distinguished by the boundary of 0.4kV, and at the same time, an equipment library that can be flexibly maintained and updated is established to facilitate managers to adjust the equipment information according to market changes. The system significantly improves the accuracy and practicability of the project budget estimation of user-side energy storage projects, and is more suitable for the needs of user-side energy storage development at this stage, providing strong support for the economic evaluation of the project.

Keywords: user-side energy storage, intelligent integrated energy planning simulation design platform, project budget estimates, item classification

1 Introduction

With the transformation of the global energy structure and the large-scale application of renewable energy, the role of user-side energy storage technology in the power system has become increasingly prominent [1,2]. User-side energy storage can not only improve the flexibility and stability of the power grid, but also effectively use renewable energy, reduce energy waste, and improve energy efficiency. However, due to the high investment cost of user-side energy storage projects and the involvement of multiple complex technical links, accurate and comprehensive project budget estimates [3] are essential for the successful implementation of the project.

In the face of the rapid development of modern user-side energy storage technology, the traditional engineering budget estimation system has gradually shown its

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limitations. On the one hand, existing budget estimation methods often treat battery systems, converters and transformers as independent units for estimation, ignoring the characteristics of modern integrated energy storage systems, resulting in the cost of some important components being double-counted or omitted. On the other hand, the existing system fails to fully consider the impact of different grid-connected voltage levels [4-6] on project costs, and lacks a unified standard to deal with other expenses and basic preparation costs, which makes it difficult to directly compare the budget estimates between different projects. In addition, due to the rapid iteration of energy storage technology, new products and technologies continue to appear in the market, but the equipment library in the existing budget estimation system is lagging behind, which cannot reflect the latest market dynamics and technological progress in a timely manner, resulting in a disconnect between the budget estimation results and the actual situation.

In order to solve the above problems, this paper constructs a new classification system for budget estimation of user-side energy storage projects based on the intelligent comprehensive energy planning simulation and design platform, which significantly improves the accuracy and practicability of budget estimation.

2 Overview of the budget Estimate of the User-Side Energy Storage Design Project

2.1 Introduction to Project Budget Estimates

Project budget estimation is a key part of the preliminary evaluation of a project, providing an important financial basis for decision-makers by estimating the amount of capital required for the entire process from design to completion [7,8]. For user-side energy storage projects, accurate project budget estimation not only helps investors to reasonably allocate funds and effectively control cost risks, but also promotes the optimal selection of technical solutions to ensure the economic and technical feasibility of the project. In addition, accurate budget estimation data is also an important reference for the government to formulate relevant subsidy policies and support measures.

A comprehensive estimate of the user-side energy storage project usually covers the following aspects: equipment purchase cost (including the cost of key equipment such as battery system, converter and transformer), installation and commissioning fee (involving the installation of equipment and commissioning work before initial operation), civil and other engineering costs (such as site preparation and infrastructure construction costs), grid-connected access fee (which varies according to the grid-connected voltage level), Other expenses (e.g. design consulting fees and supervision service fees) and basic preparation fees (to deal with cost increases due to unforeseen factors that may arise during the construction of the project).

With the rapid development of user-side energy storage technology, the traditional engineering budget estimation system is difficult to meet the current complex and changeable application requirements. Therefore, it is particularly important to establish a more accurate and adaptable project budget estimation system. The purpose of this paper is to construct a classification system for engineering budget estimation suitable for modern user-side energy storage projects through innovative methods, so as to improve the accuracy and practicability of budget estimation.

2.2 The Current Situation and Existing Problems of the Project Budget Estimation Study

In recent years, with the rapid development of user-side energy storage technology, scholars and engineering practitioners at home and abroad have conducted extensive research on the engineering budget estimation of energy storage projects. These studies focus on cost composition analysis, economic evaluation methods, and policy and market implications. Many studies have discussed in detail the cost structure of user-side energy storage systems, including the cost of key equipment such as battery systems, converters, and transformers, as well as installation and commissioning costs, civil and other engineering costs, and grid-connected access fees, etc., to improve the accuracy of budget estimates by refining cost items. In order to evaluate the economic benefits of user-side energy storage projects, some studies have proposed a variety of economic evaluation indicators, such as net present value, internal rate of return, and payback period, to help decision-makers better understand the financial performance of the project. In addition, some studies also focus on the impact of policy subsidies, tax incentives, and electricity market price fluctuations [9] on the cost of energy storage projects, which may vary greatly in different countries and regions, so it is necessary to consider the specific local situation.

Despite numerous research achievements, existing engineering budget estimation systems have several practical limitations. Current systems often treat battery systems, converters, and transformers as independent units, overlooking the integrated nature of modern energy storage systems. This can lead to double-counting or omission of costs, affecting budget accuracy. Moreover, these systems do not fully account for the impact of different grid connection voltage levels on project costs. Significant differences in equipment selection, construction difficulty, and safety requirements between voltages below and above 0.4kV need to be reflected in budget estimates. Existing systems also lack a unified standard for other costs and basic reserve costs, making it difficult to compare budget estimates across projects. This increases the complexity and uncertainty of project evaluations. Additionally, the rapid evolution of energy storage technology means new products and technologies are constantly emerging. However, the equipment libraries in current budget systems are often outdated, leading to a disconnect between budget estimates and actual market conditions.

In summary, current user-side energy storage budget systems have limitations in addressing new technologies and demands. There is an urgent need to develop a more scientific and practical budget estimation system to adapt to technological advancements and market changes. In the following chapters, we will introduce an innovative system to address these issues and improve the accuracy and practicality of budget estimates.

3 Construction of Engineering Budget Estimation System Based on Intelligent Comprehensive Energy Planning Simulation Design Platform

3.1 Overview of Intelligent Integrated Energy Planning Simulation and Design Platform

The Intelligent Integrated Energy Planning Simulation and Design Platform is a digital tool that provides auxiliary decision support for the proposal or feasibility study phases of energy projects. As shown in Figure 1, this platform establishes an engineering estimate system process based on smart integrated energy planning and simulation design. The core modules of the platform include user interface, project management, planning and design, engineering estimates, equipment library, financial evaluation, report generation, and database, providing strong support for the planning and design of user-side energy storage projects.

The planning and design aspect of the platform mainly covers project data collection, load analysis, equipment selection, engineering estimates, financial evaluation, and scheme comparison. Equipment

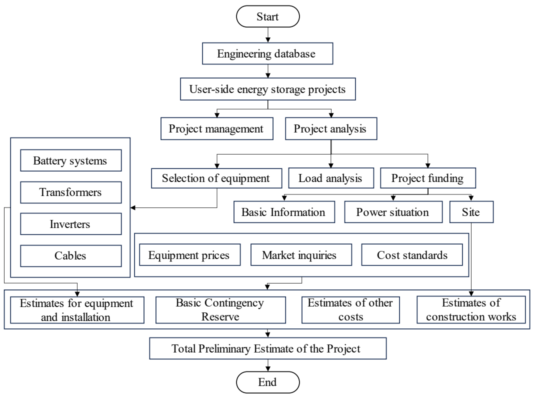

Fig. 1. Flow chart for the construction of engineering budget estimation system based on simulation design platform.

selection includes sub-modules such as battery systems, transformers, inverters, and cables, which are closely linked to the equipment and installation engineering estimate tables.

To ensure that information on equipment models and prices can respond promptly to market changes, the platform has set up a management end. Administrators can log into the management end to add new equipment, input equipment prices, key parameters, manufacturers' information, and update existing equipment. Additionally, based on equipment prices, market inquiries, current management regulations, and cost standards, the engineering estimate tables are dynamically adjusted. Through this flexible design and adjustment, the platform can provide real-time updated data for the engineering estimates of user-side energy storage, thereby achieving better investment returns, more rational equipment combinations, and intelligent scheme assessments, as well as automated decision adjustments.

3.2 System of Categorized Entries in the Proposed Budget for User-Side Energy Storage Project

Estimates for Equipment and Installation. In the project estimate of user-side energy storage projects, the estimate of equipment and installation works is one of the most critical parts. In order to improve the accuracy and practicability of the estimate, a new classification system for the estimate of equipment and installation works is proposed. The system takes full account of the characteristics of modern integrated battery systems and classifies the equipment in detail according to the actual application requirements.

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Table 1. Table of estimates for energy storage equipment and installation.

				Unit Price (CNY)			Total Price (ten thousand CNY)			
No.	Equipment & Name	Unit	Quantity	Equipment Cost	Installation Cost	Including: Material Cost	Equipment Cost	Installation Cost	Including: Material Cost	Total (ten thousand CNY)
I	Equipment and Installation Engineering									
1	Energy Storage Equipment and Installation Engineering									
1.1	Energy storage equipment and installation									
1.1.1	Battery system (triple choice association)	Unit/Wp								
1.1.2	PCS	Set								

1.2	Collection Circuit	
1.2.1	AC Cable (Specific Model, from PCS to Step-up Transformer)	m
1.2.2	AC Cable (Specific Model, from Step-up Transformer to Grid Connection Point)	m
1.3	Grounding	
1.3.1	Ground Busbar	m
1.3.2	Grounding Electrodes	Rods
1.4	Subsystem Commissioning	
1.4.1	Energy Storage Array System Commissioning	Item

Transformer and distribution equipment and installation works. Special attention has been given in the estimates for the substation and distribution equipment and installation projects to the impact of different grid-connected voltages on the project estimates. Using 0.4kV as the dividing line, there are significant differences between low-voltage (below 0.4kV) and high-voltage (above 0.4kV) grid-connection projects in terms of equipment selection, construction difficulty and safety requirements. For example, high-voltage grid-connected projects may require higher-level transformers and other auxiliary equipment, while low-voltage grid-connected projects may focus more on converter efficiency and reliability. The platform automatically generates corresponding estimation forms according to different grid-connected voltage levels. For low-voltage grid-connected projects, the grid-connected cabinets can meet the grid-connected requirements, while the cost of the box-type substation part will be incurred only when the grid-connected voltage is higher than 0.4kV. The schedule of estimates for electrical substation equipment and installation is shown in Table 2.

Table 2. Schedule of Estimates for Electrical Substation Equipment and Installation.

No.	Equipment & Name	Unit	Quantity	Unit Price (CNY)			Total Price (ten thousand CNY)			Total (ten thousand CNY)
				Equipment Cost	Installation Cost	Including: Material Cost	Equipment Cost	Installation Cost	Including: Material Cost	

2	Power Distribution Equipment and Installation Engineering	
2.1	Energy Storage Grid Connection Cabinet (Choose 2.2 if grid voltage is above 0.4kV)	Unit
2.2	Prefabricated Substation	
2.2.1	Transformer (Specific Model)	Unit
2.2.2	High Voltage Grid Connection Cabinet	Panel
2.2.3	High Voltage Switchgear Cabinet	Panel
2.2.3.1	Inlet Cabinet	m
2.2.3.2	Outlet Cabinet	
2.2.3.3	PT Cabinet	
2.2.3.4	Metering Cabinet	
2.2.3.5	Reactive Power Compensation Cabinet (Capacitor Compensation Cabinet)	Set
2.2.4	Station Transformer Cabinet	
2.2.5	Primary Prefabricated Cabin	Set

Control and protection equipment and installation works. The table of estimates for control and protection equipment and installation works is shown in Table 3. In user-side energy storage projects, control and protection equipment and its installation works are key components to ensure safe and stable operation of the system.

Table 3. Schedule of estimates for control and protection equipment and installation works.

No.	Equipment & Name	Unit	Quantity	Unit Price (CNY)			Total Price (ten thousand CNY)			
				Equipment Cost	Installation Cost	Including: Material Cost	Equipment Cost	Installation Cost	Including: Material Cost	Total (ten thousand CNY)
3	Control and Protection Equipment and Installation Engineering									
3.1	BMS (Battery Management System)	Set								
3.2	EMS (Energy Management System)	Set								
3.3	Automation Monitoring (Supervision) System	Set								
3.4	Remote Communication Device	Set								
3.5	Monitoring Station Communication Equipment	Set								
3.6	Screen Common Measurement and Control Device	Set								
3.7	Power Quality Monitoring and Energy Data Acquisition Device	Set								

3.8	Relay Protection System	Set			
3.9	Anti-Islanding and Fault Isolation Device	Set			
3.10	Video Surveillance System	Set			
3.11	Anti-Reversal System	m			
3.12	Environmental Monitoring Device	Set			
3.13	Secondary Prefabricated Cabin	Set			

Estimates of Construction Works. Construction engineering costs mainly include energy storage power station construction, building construction, and transportation and other related engineering.

Preliminary Estimate of Energy Storage Power Station Construction. As shown in Table 4, the energy storage power station construction includes site leveling, foundation work for power generation equipment, foundation work for collection and power distribution equipment, collection line engineering, grounding engineering, and fencing engineering. The preliminary estimate provides a comprehensive cost framework for the project.

Table 4. Preliminary Estimate of Energy Storage Power Station Construction.

No.	Project or Cost Item	Unit	Quantity	Unit Price (CNY)	Total (ten thousand CNY)
II	Construction Engineering	CNY			
1	Energy Storage Power Station Construction	CNY			
1.1	Site Leveling	/			
1.2	Foundation Work for Energy Storage Equipment	/			
1.3	Foundation Work for Collection and Power Distribution Equipment	/			
1.4	Collection Line Engineering	m			
1.5	Grounding Engineering	/			
1.6	Fencing Engineering	/			

Preliminary Estimate of Building, Transportation, and Other Engineering. As shown in Table 5, other construction engineering includes environmental protection engineering, soil and water conservation engineering, labor safety and industrial hygiene engineering, and other related engineering.

Table 5. Preliminary estimate of building, transportation, and other engineering.

No.	Project or Cost Item	Unit	Quantity	Unit Price (CNY)	Total (ten thousand CNY)
II	Construction Engineering	CNY			
2	Building Construction	/			
3	Transportation Engineering	/			
4	Other Construction Engineering	/			
4.1	Environmental Protection Engineering	Item			
4.2	Soil and Water Conservation Engineering	Item			
4.3	Labor Safety and Industrial Hygiene Engineering	Item			
4.4	Other Engineering	/			

Estimates of Other Costs. The preliminary estimate of other costs includes land acquisition costs for the project, project management fees, production preparation fees, survey and design fees, and other related fees. The detailed preliminary estimate table for other costs, as shown in Table 6, lists all indirect costs beyond the direct engineering costs (such as equipment procurement and installation and commissioning fees), providing a comprehensive reflection of the total cost structure of the project.

Table 6. Preliminary estimate of other costs.

No.	Project or Cost Item	Unit	Rate (%) /Quantity	Base for Calculation (ten thousand CNY) /Unit Price (CNY)	Total (ten thousand CNY)
III	Other Costs	CNY			
1	Land Acquisition Costs for the Project	CNY			
2	Project Management Fees	CNY			
2.1	Pre-Construction Costs	CNY			
2.2	Construction Management Fee	%			
2.3	Construction Supervision Fee	%			
2.4	Project Consulting Service Fee	%			

Table 6. Preliminary estimate of other costs.

No.	Project or Cost Item	Unit	Rate (%) /Quantity	Base for Calculation (ten thousand CNY) /Unit Price (CNY)	Total (ten thousand CNY)
2.5	Technical and Economic Review Fee	%			
2.6	Quality Inspection and Testing Fee	%			
2.7	Standardization and Quota Compilation Fee	%			
2.8	Project Acceptance Fee	%			
2.9	Engineering Insurance Fee	%			
3	Production Preparation Fee	%			
4	Survey and Design Fee (Including Feasibility Study Fee)	CNY			
5	Other Fees	CNY			

Basic Contingency Reserve. The basic contingency reserve for this project is shown in Table 7.

Table 7. Preliminary estimate of basic contingency reserve.

No.	Project or Cost Item	Unit	Rate (%) /Quantity	Base for Calculation (ten thousand CNY) /Unit Price (CNY)	Total (ten thousand CNY)
IV	Basic Contingency Reserve	%			

Total Preliminary Estimate of the Project. Table 8 is the total preliminary estimate table for the project. The total preliminary estimate table summarizes and calculates the costs of all the different components.

Table 8. Total Preliminary Estimate of the Project

No.	Project or Cost Item	Equipment Purchase Cost (ten thousand CNY)	Construction and Installation Cost (ten thousand CNY)	Other Costs (ten thousand CNY)	Total (ten thousand CNY)	Percentage of Total Investment (%)
I	Equipment and Installation Engineering					

1	Energy Storage Equipment and Installation
2	Power Distribution Equipment and Installation
II	Construction Engineering
1	Power Generation Field Engineering
2	Substation Engineering
3	Building Construction
4	Transportation Engineering
5	Other Construction Engineering
III	Other Costs
1	Land Acquisition Costs for the Project
2	Project Management Fees
3	Production Preparation Fee
4	Survey and Design Fee (Including Feasibility Study Fee)
5	Other Fees
	Subtotal (I~III)
IV	Basic Contingency Reserve
	Total Static Investment (I~IV)
	Unit Static Investment (CNY/kW)
V	Price Difference Contingency Reserve

4 Application Case

In order to verify the validity and practicability of the above constructed classification system of user-side energy storage project estimates, an example of an integrated smart energy project with an energy storage plant is analyzed. The case is a low-voltage grid-connected energy storage project within a commercial complex, aiming to improve energy utilization efficiency and reduce peak electricity costs by installing a user-side energy storage system.

4.1 Project Background

The project is located at latitude 32.067°N, longitude 118.77°E, and elevation of about 18 m. The project user tariff type is commercial and industrial, the incoming voltage level is 1-10kV, and the access voltage level is 0.22kV, which belongs to the high-voltage incoming and low-voltage grid-connected energy storage project.

4.2 Load Analysis

Load Analysis calculates monthly electricity consumption using the Historical Data Method and the Long Term Typical Day Method. The Historical Data Method allows the user to customize the configuration of power consumption for different time periods (e.g., peak, peak, weekday, and valley) to derive the total monthly power consumption, while the Long Term Typical Day Method is based on the statistical analysis of the power load data of different types of buildings (e.g., hospitals, hotels, commercial, office, and industrial buildings) in a specific area to deduce the total monthly power demand. In this project, each hourly segment of the typical day has a power of 1000 kW for 24 hours, showing a stable load pattern.

4.3 The Application Process

Load Analysis calculates monthly electricity consumption using the Historical Data Method and the Long Term Typical Day Method. The Historical Data Method allows the user to customize the configuration of power consumption for different time periods (e.g., peak, peak, weekday, and valley) to derive the total monthly power consumption, while the Long Term Typical Day Method is based on the statistical analysis of the power load data of different types of buildings (e.g., hospitals, hotels, commercial, office, and industrial buildings) in a specific area to deduce the total monthly power demand. In this project, each hourly segment of the typical day has a power of 1000 kW for 24 hours, showing a stable load pattern.

Selection of Equipment.

Battery System Selection. Battery system selection is one of the core steps in the design and implementation of user-side energy storage systems, which is not only related to the performance and economy of the energy storage system, but also involves many aspects such as safety, compatibility and compliance. Intelligent integrated energy planning simulation platform establishes a flexible and updated equipment library, which includes the information of mainstream battery systems, converters, transformers, cables and other products in the market to facilitate managers to adjust the equipment information according to market changes. According to the project requirements in the platform battery system list selected a manufacturer of ST129CP-50HV battery cabinet as energy storage equipment. Table 9 lists the battery system selection. The battery system type is an integrated cabinet, which integrates the battery module and converter, but still needs an external transformer to realize the connection with the power grid.

Table 9. Battery system selection.

Manufacturer	Model	Type	Quantity	System Capacity Configuration (kW)	Total Battery System Capacity (kW)
Sungrow	ST129CP-50HV	All-in-one Cabinet	3	60.00	387.00

Transformer Selection. Since the battery system in this case is selected as an integrated cabinet, including the converter, the transformer needs to be selected as a separate device. The platform automatically generates the recommended transformer capacity based on the total power of the selected converter. In this case, the total power of the converter is 150 kW and the recommended transformer capacity is 156.25 kVA, so the transformer is selected as ZGSWB11-Z-160 with a capacity of 160 kVA, as shown in Table 10.

Table 10. Transformer Selection.

Manufacturer	Model	Rated Frequency (Hz)	Primary Nominal Voltage (kV)	Secondary Nominal Voltage (kV)	Rated Capacity (kVA)	Price (CNY)
Eaton	ZGSWB11-Z-400	50	10	0.4	400	188800
Eaton	ZGSWB11-Z-200	50	10	0.4	200	210000
Eaton	ZGSWB11-Z-250	50	10	0.4	250	199900
Eaton	ZGSWB11-Z-160	50	10	0.4	160	200000

Cable. The selection of cables is mainly based on the “Technical Regulations for the Design of DC Power Supply Systems for Power Engineering” (DL/T5044-2014) and

"Cable Design Standards for Power Engineering" (GB 50217-2018), and the specific model parameters are shown in Table 11.

Table 11. Cable.

Battery Module Rated Current(A)	Cable Material	Cable Length (m)	Cable Type	Unit Price (CNY/m)	Total Price (CNY)
72.17	Copper	1000	PV1-F 4KV 1*6	7	7000.00

Project Budget Estimates. After completing the project equipment selection, the intelligent integrated energy simulation planning platform generates a detailed project estimate table based on the selected equipment and system configuration. This section will provide a comprehensive estimate of the various costs for this case based on the preliminary design program. Table 12 is the total preliminary estimate for the project.

Table 12. Total preliminary estimate of the project.

No.	Project or Cost Item	Equipment Purchase Cost (ten thousand CNY)	Construction and Installation Cost (ten thousand CNY)	Other Costs (ten thousand CNY)	Total (ten thousand CNY)	Percentage of Total Investment (%)
I	Equipment and Installation Engineering	107.07	8.06		115.13	78.85
1	Energy Storage Equipment and Installation	0.57	2.42		2.99	2.05
2	Power Distribution Equipment and Installation	1.00	0.30		1.30	0.89
II	Construction Engineering	105.50	5.34		110.84	75.91
1	Power Generation Field Engineering		10.40		10.40	7.12
2	Substation Engineering		10.28		10.28	7.04
3	Building Construction		0		0	0.00
4	Transportation Engineering		0		0	0.00
5	Other Construction Engineering		0.12		0.12	0.08
III	Other Costs			17.62	17.62	12.07
1	Land Acquisition Costs for the Project			0.00	0.00	0.00
2	Project Management Fees			14.84	14.84	10.16
3	Production Preparation Fee			2.78	2.78	1.90
4	Survey and Design Fee (Including Feasibility Study Fee)			0.00	0.00	0.00

5	Other Fees			0.00	0.00	0.00
	Subtotal (I~III)	107.07	18.46	17.62	143.15	98.04
IV	Basic Contingency Reserve				2.86	1.96
	Total Static Investment (I~IV)				146.01	100
	Unit Static Investment (CNY/kW)				24335.00	
V	Price Difference Contingency Reserve				0	

5 Conclusion

This paper introduces a new engineering estimation system to address the limitations of traditional systems in the context of rapidly advancing user-side energy storage technology. Key features include:

- Equipment Categorization: Modern battery systems are divided into battery cabinets, integrated cabinets, and energy storage systems, simplifying selection and ensuring budget accuracy;
- Voltage Level Differentiation: The system distinguishes between low-voltage (below 0.4kV) and high-voltage (above 0.4kV) grid connections, providing more accurate cost estimates;
- Flexible Equipment Library: A dynamic equipment library includes information on mainstream products and allows online updates, enhancing system adaptability;

In summary, this new system improves the accuracy and practicality of user-side energy storage project estimates, supporting better pre-assessment. Future research will validate and refine the system in real-world applications.

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