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A Fuzzy-ANP Approach for Comprehensive Benefit Evaluation of Grid-Side Commercial Storage Project

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Abstract: With the increasing demand for clean and low-carbon energy, high proportion of renewable energy has been integrated into the receiving-end grid. The grid-side energy storage project can ensure the safe and stable operation of the grid, but it still faces many problems, such as high initial investment, difficult operation and maintenance, unclear profit model, lack of business mode. Therefore, it is of great significance to evaluate the comprehensive benefit of energy storage projects in order to guide the sustainable development of large-scale energy storage projects and power system. By studying the technical and economic characteristics of energy storage, this paper establishes a comprehensive evaluation system from four dimensions of energy efficiency, economic, social, and environmental benefit. Combined with typical business modes and determining the subdivision index system of different modes, the comprehensive benefit evaluation model of grid-side commercial storage project based on Fuzzy-Analytic Network Process (ANP) approach is established. Empirical analysis of a 100-megawatt storage project is carried out to evaluate the project benefits comprehensively, the potential problems of the market development and business mode of the grid-side large-scale storage project are discussed, and the future development orientation and suggestions are put forward.

Keywords: large-scale storage projects; comprehensive benefits; business mode; fuzzy-analytic network process

1. Introduction

In recent years, the scale of renewable energy in the receiving power grid has been continuously expanded, which has seriously affected the safe and stable operation of the power grid and its ability to absorb renewable energy [1,2]. Large-scale energy storage is beneficial to improve the peak regulation ability, stability, and flexibility of the receiving end power grid [3]. However, the development and application of large-scale energy storage are still faced with many problems, such as excessive initial investment, difficult operation, unclear profit model, and immature business mode [4,5].

Moreover, the evaluation methods of energy storage are different because of their different roles in various fields. At present, most of the benefit evaluation and analysis of energy storage applications are based on economic consideration and lack of comprehensive benefit evaluation for environment and society. As a result, the benefits of energy storage in improving the flexibility and stability of power grid and relieving the pressure of peak regulation have not been reflected [6,7]. Therefore, it is urgent to establish the comprehensive benefit evaluation model of grid-side energy storage project, so as to provide decision support for improving the benefits and utilization of energy storage project.

In terms of applicable scenarios and business modes of energy storage, Schoenung S. M. et al., 1996, discussed the application opportunities of energy storage technology in the rapidly changing American energy market [8]. Sioshansi R. et al., 2012,

investigated the main obstacles to the development of energy storage system in the U.S., and put forward suggestions to help solve these obstacles [9]. Li J. et al., 2019, summarized the application scenarios of energy storage in power system from the perspective of various stages of industrial development, and put forward relevant suggestions and conclusions [10]. DNV GL Company, Sandia National Laboratories, and the U.S. Department of Energy developed the ES-Select software jointly, which could calculate the technical and economic feasibility of energy storage under a given application scenario. However, the software could not carry out economic research on a single storage station [11].

The researches on the benefit evaluation of energy storage under the specific business mode is a key issue for the matured and large-scaled development. Poonpun P. et al., 2008, analyzed the economic benefits of energy storage systems, and verified the economic feasibility of energy storage arbitrage in the case of high peak-valley price difference [12]. Skyllas-Kazacos M, et al., 1997, proposed a net profit calculation method for electrochemical energy storage system in view of various application scenarios [13]. Sasaki T et al., 2004, established a net profit calculation model of typical energy storage and evaluated the application economy from typical application value aspects in power system, including delay of power grid upgrading and reconstruction, peak-valley arbitrage, frequency regulation auxiliary services, etc. [14]. Researches also put forward the energy storage site selection and capacity planning with the application indicators of energy storage investment cost, operating period cost, equipment replacement cost, power distribution online shopping cost and reliability cost [15,16].

Therefore, this study aims to build a comprehensive benefit evaluation system for large-scale energy storage projects, in order to evaluate the comprehensive benefits accurately and quantitatively based on the demand of receiving power grid and business modes. The main contributions of this study are as follows:

(1) A comprehensive benefit evaluation index system has been established, which fully takes into account the actual operation status of grid-side energy storage projects and has more practical and theoretical value than financial evaluation. Refer to existing researches and literatures [17–21], take energy efficiency, economic benefit, social benefit, and environmental benefit as the four dimensions of the comprehensive benefit evaluation index system.

(2) Summarized the current grid-side energy storage business modes in China. Consider the differences among modes, different indicators in the evaluation index system for specific business mode are selected to evaluate the comprehensive benefits, which can avoid the ambiguity of the evaluation process and ensure the accuracy of evaluation results.

(3) Considering that the energy storage industry is in a rapid and unstable stage, the Analytic Network Process (ANP) and comprehensive fuzzy evaluation methods are combined to apply the comprehensive benefits evaluation of grid-side energy storage projects.

(4) Through the empirical analysis of 100-megawatt storage project, the key influencing factors of comprehensive benefits are extracted. It would help promote the innovation and breakthrough of energy storage policy mechanism and ensure the orderly and sustainable development of energy storage.

2. Materials and Methods

The paper conducted a comprehensive evaluation system from energy efficiency, economic, social, and environmental benefits four dimensions based on literature review, and sub-dividable systems are identified according to typical business modes. Then, the fuzzy comprehensive evaluation method and network analytic hierarchy process are combined to reflect the interaction among indicators and evaluate the comprehensive benefits scientifically and quantitatively. Finally, a 100-megawatt storage project in Zhenjiang are applied for the empirical analysis. The methodology of this paper is shown in Figure 1.
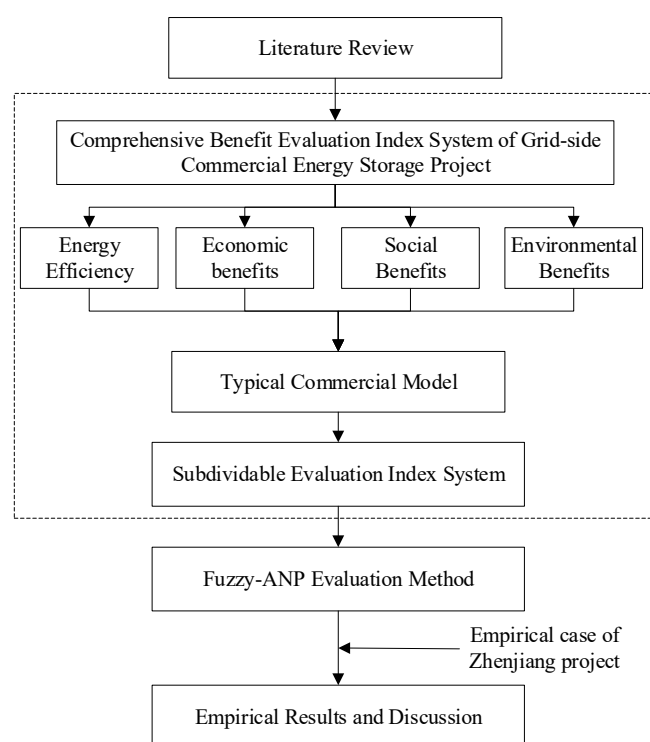
Figure 1. Methodology of comprehensive benefit evaluation of grid-side commercial storage project.

2.1. Comprehensive Benefit Evaluation Index System of Grid-Side Commercial Storage Project

2.1.1. Comprehensive Benefit Evaluation Index System

Based on the technical and economic characteristics of energy storage and the application value in typical scenarios [22–24], the indicators that affect the comprehensive benefits of energy storage are collected by literature review. Taking the research frequency and the emphasis importance, the framework of comprehensive benefits of the energy storage projects is established from energy efficiency [25–27], economic benefits [28–33], social benefits [34,35], and environmental benefits [36,37]. Then, the final evaluation index system were determined by experts interviews with relevant experts from North China Electric Power University, NARI Group, State Grid Energy Research Institute and Jiangsu Institute of Economic Research and other institutions, as shown in Table 1.

Energy Efficiency

The energy efficiency indicators are selected according to the performance of the energy storage technology and its application in the receiving-end power grid. Technology evaluation indicators vary according to different types of battery energy storage systems, including cell voltage (A1), energy density (A2), power density (A3), and self-discharge rate (A4). Application performance indicators are based on different application scenarios, where cycle life (A5), charge and discharge efficiency (A6), stability (A7), and responsiveness (A8) indicators are selected. The stability and responsiveness indicators adopt 1–10 points expert scoring method to determine the score.

Table 1. Comprehensive benefit evaluation index system for storage project.

First Level Indicator	Second Level Indicator	Third Level Indicator	Indicator Preference	Explanation
Energy efficiency (A)	Technology	Cell voltage (A_1)	+	Standard voltage of each battery
		Energy Density (A_2)	+	Effective storage capacity of per unit mass of material
		Power density (A_3)	+	Effective storage power of per unit mass of material
		Self-discharge rate (A_4)	−	The retain ability when the battery with open circuit state
	Application	Cycle life (A_5)	+	The maximum cycle number that the system could withstand
		Charge and discharge efficiency (A_6)	+	The ratio of the released energy to the initial energy
		Stability (A_7)	+	Ability to maintain stable operation under external influence
		Responsiveness (A_8)	+	Required time for system response
Economic benefits (B)	Cost	Construction cost (B_1)	−	Construction cost of project
		Capacity cost (B_2)	−	Cost of configuring battery system
		Power cost (B_3)	−	Cost of conversion equipment and other facilities
		Operation and maintenance cost (B_4)	−	Operation & maintenance costs and rental fees of storage systems
	Profit	Peak-to-valley price spread (B_5)	+	Profit from peak shaving and valley filling with storage system
		Saving investment (B_6)	+	Saving investment of grid equipment due to storage system
		Government subsidy (B_7)	+	Policy subsidy rewards of energy storage systems
		Network loss reduction (B_8)	+	Annual revenue from reducing line loss due to storage system
		Recycle revenue (B_9)	+	Recyclable value at the end of the energy storage system life
Social benefits (C)	Reliability	Change value of power shortage rate (C_1)	+	$=\text{LOLP}_{\text{with storage}} - \text{LOLP}_{\text{without storage}}$ LOLP: loss of load probability
		Change value of power available rate (C_2)	+	$=\text{ASAI}_{\text{with storage}} - \text{ASAI}_{\text{without storage}}$ ASAI: average service availability index
	Frequency regulation benefit	Frequency regulation multiple (C_3)	+	$= \sigma f_{\text{with storage}} / \sigma f_{\text{without storage}}$ σf: frequency standard deviation
		Frequency regulation contribution rate (C_4)	+	$=(\text{CPS}_{\text{with storage}} - \text{CPS}_{\text{without storage}})/\text{CPS}_{\text{without storage}}$ CPS: control performance standard
Environmental benefits (D)	Clean consumption	Change rate of clean consumption (D_1)	+	$=(\text{NC}_{\text{with storage}} - \text{NC}_{\text{without storage}})/\text{NC}_{\text{without storage}}$ NC: regional new energy consumption amount
	Low carbon reduction	Emission reduction revenue (D_2)	+	$=\text{Emission cost of thermal power unit} \times (\text{Storage charge quantity} + \text{NC}_{\text{with storage}} - \text{NC}_{\text{without storage}})$

Economic Benefits

The economic indicators are constructed from the perspective of cost and benefit. The costs of energy storage projects mainly include construction cost (B1), capacity cost (B2), power cost (B3), and operation and maintenance cost (B4). On the other hand, the profits are as follows: the peak-to-valley price spread (B5) is expressed as the revenue obtained from the transfer of peak load; the investment delay (B6) is determined based on the average cost of substations, transformers, transmission lines and supporting equipment that can be built less or delayed; the government subsidy (B7) is determined by regional specific policies; the network loss reduction(B8) caused by peak and valley charging and discharging is the annual revenue of reducing the line network loss due to energy storage applications; the recycle revenue (B9) refers to the recyclable value of electrodes, metal materials, and carbon materials inside the system after the end of the life of the energy storage system.

Social Benefits

When energy storage projects are applied to the receiving power grid, they can be used as backup power sources to improve supply reliability and quality and participate in frequency regulation. Reliability indicators and frequency regulation benefit indicators are selected to evaluate social benefit. In this study, the system power shortage probability change value (C1) reflected the impact of transmission failure or blockage on the available generation capacity of the system. The mathematical expression is the probability that the available power generation of the system is less than or equal to a certain constant load demand. The average power supply availability change value (C2) of the system is determined by the expected value of insufficient power and the system cut-off power, which can reflect the power supply reliability of the system. The efficiency of frequency regulation before and after the participation of energy storage is evaluated by using the high efficiency multiples of frequency regulation C3 and C4.

Environmental Benefits

Environmental indicators are selected to measure the effectiveness of energy storage in energy transition and emission reduction [38]. When energy storage projects are connected to the receiving-end grid, they can smooth the output of new energy, provide good conditions for new energy consumption, and reduce a certain amount of carbon emissions. The clean energy consumption change rate (D1) reflects the grid improvement to adapt to new energy capacity, which is measured by the change rate of regional new energy consumption before and after the energy storage put into operation. Energy saving and emission reduction revenue (D2) are calculated by the electric energy emission cost of the thermal power unit and the charge of energy storage charge.

2.1.2. Benefit Evaluation System of Large-Scale Energy Storage Projects under Different Business Modes

The operated grid-side energy storage projects are mainly demonstration projects, and the business modes are mainly classified into 4 modes [39], as shown in Figure 2.

Different cost and revenue indicators need to be considered based on different business modes of energy storage projects. In the operating lease mode, the grid company only needs to consider the lease cost and operation and maintenance cost, where the recycle revenue cannot be included; in the contract energy management mode, the cost and revenue are calculated according to the contract; in the independent transaction entity mode, there is no need to consider costs and economic benefits on the power grid side, but it can improve the reliability of power supply. The detailed evaluation system under each business mode is shown in Table 2.
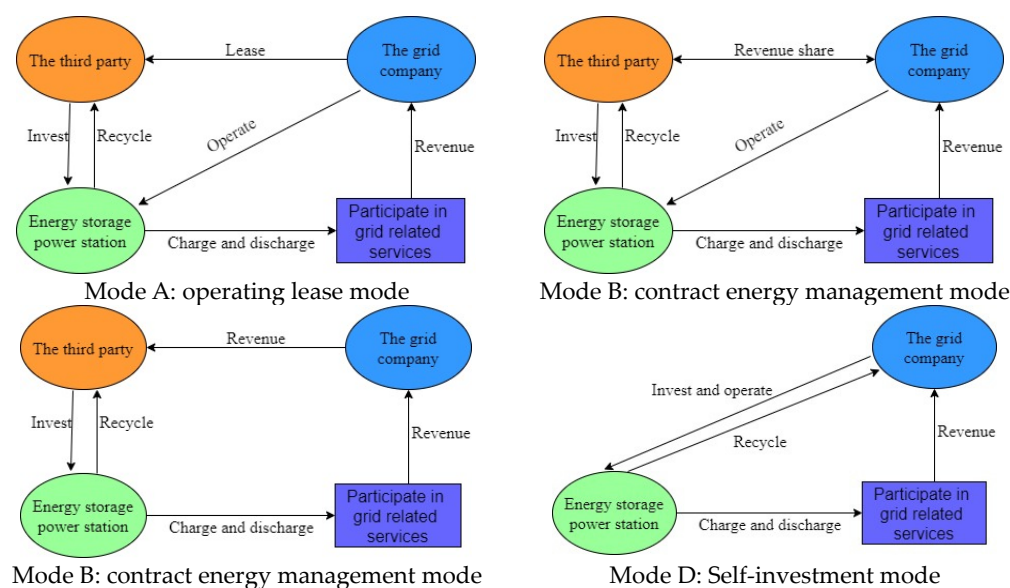
Figure 2. Four typical business modes.

Table 2. Comprehensive benefit evaluation index system of energy storage projects under different business modes.

Indicators	A	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	C_1	C_2	C_3	C_4	D_1	D_2
Mode A	√				√	√	√	√	√		√	√	√	√	√	√
Mode B	√				√	√	√	√	√		√	√	√	√	√	√
Mode C	√										√	√	√	√	√	
Mode D	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

2.2. Fuzzy-ANP Evaluation Method of Grid-Side Commercial Storage Project

The Analytic Network Process (ANP) can deal with more disorderly and complex decision-making problems and has strong applicability on dependency and mapping structure [40], which is used it to determine the index weight. The fuzzy comprehensive evaluation is more in line with the decision-maker's actual situation [41,42], which is used to determine the index value. These two methods are widely used in the energy field because they can give full play to their respective characteristics during evaluation and decision-making [43–47]. The Fuzzy-ANP method combining ANP and fuzzy comprehensive evaluation method to further research the established index system.

Step 1: Establish a network hierarchy.

A network hierarchical structure is established for the comprehensive benefit evaluation of the receiving end grid-side energy storage project firstly. The control layer contains four criteria B1–B4, namely Energy efficiency, Economy, Society, and Environment. The network layer contains four indicators sets as shown in Figure 3, where energy efficiency indicators, economic indicators, social indicators, and environmental indicators have mutual influences among groups.
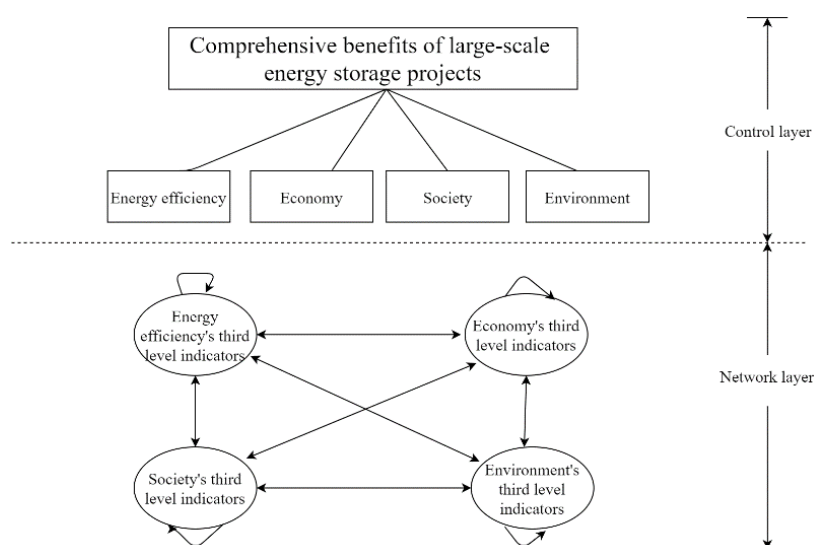
Figure 3. The hierarchical structure of the comprehensive benefit evaluation network of energy storage.

Step 2: Construct a judgment matrix.

The judgment value of the judgment matrix is obtained by comparing the importance of any two elements *i* and *j* in the element group. The judgment value is 1 to 9. Then solve the maximum eigenvalue α_{max} of the judgment matrix X according to the formula XW = α_{max}W, the sorting vector $\begin{bmatrix} w_{i1}^{(jk)} & w_{i2}^{(jk)} & \dots & w_{in_i}^{(jk)} \end{bmatrix}^T$ is obtained.

Step 3: Consistency check.

The random consensus ratio (*CR*) is the standard used to test whether the judgment matrix meets the consistency requirements in the network analytic hierarchy process. The *CR* solution formula is as follows:

$$CR = CI/RI \tag{1}$$

where $CI = (\alpha_{max} - n)/(n-1)$, *CI*. is consistency Index; *RI* is the average random consistency index. When the *CR* value is less than 0.1, the inconsistency of the judgment matrix is within the allowable range, and the judgment decision is reasonable.

Step 4: Construct the initial hypermatrix.

By continuously adjusting the elements in the judgment matrix to make all judgment matrices meet the consistency requirements, the local weight vector matrix can be written into the matrix form. For all local weight vector matrices, the systematic hypermatrix W is formed under the criterion of B_s. Since there are m B_s criteria in the control layer, there are m hypermatrices similar to the above criteria. The sub-block W_{ij} of each hypermatrix is column normalized, but the entire hypermatrix W is not column normalized. Therefore, the hypermatrix needs to be weighted, using B_s as the criterion, and then C_j as the sub-criterion. Under B_s, the relative importance of each element group and C_j is compared one by one. Finally, N comparison matrices are formed, and the weighting matrix *A* is obtained as shown in Formula (2) [48].

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{2}$$

A is a non-negative matrix with a column sum of 1. Since there are m elements in the control layer, there are a total of m matrices similar to A. Normalize W and weight its

elements to obtain a weighted hypermatrix $\overline{W} = \overline{W_{ij}}(i, j = 1, 2 \ldots N)$, where $\overline{W_{ij}} = a_{ij}W_{ij}$. The number of such weighted hypermatrices is m.

Step 5: Calculate limit hypermatrix.

The stabilization process is to calculate the limit relative ranking vector by calculating the limit of each hypermatrix:

$$W^{\infty} = \lim_{\kappa \to \infty} \left(\frac{1}{N}\right) \sum_{\kappa=1}^{N} \overline{W}^{\kappa} \tag{3}$$

If the limit converges, the value of the corresponding row of the matrix is the stability weight of each evaluation indicators.

Step 6: Determine the comment set.

The comment set is the set of all the evaluation results that the evaluators may make to the evaluation objects. Quantitative indicators will be determined through field research, literature search and other methods, combined with the actual situation of the area where the evaluated objects are located to determine the theoretical upper and lower limits [a, b] of the indicator. [a, b] is divided into four equal parts [a, c], [c, d], [d, e], and [e, b], if an indicator is a positive indicator, it corresponds to the four levels of {unqualified, qualified, good, excellent}; if an indicator is a negative indicator, vice versa [49]. Qualitative indicators will be determined by scoring by experts from 1 to 10, among which [0;2.5], [2.5;5], [5.7;5], and [7.5;10] correspond to (unqualified, qualified, good, excellent) respectively.

Step 7: Construct fuzzy relation matrix R and carry out fuzzy evaluation of single benefit indicators.

When obtaining the single-factor membership vector, this paper adopts the triangular fuzzy membership function as shown in Figure 4, and substitutes the single-factor's value of the evaluated large-scale energy storage project into the following unqualified function, qualified function, good function, and excellent function:

(1) Unqualified function

$$f_1(x) = \begin{cases} 1, x \in [a, \frac{a+c}{2}] \\ \frac{2d-2x}{2d-a-c}, x \in (\frac{a+c}{2}, d] \\ 0, x \in (d, b] \end{cases} \tag{4}$$

(2) Qualified function

$$f_2(x) = \begin{cases} \frac{2x-2a}{e-a}, x \in [a, \frac{a+e}{2}] \\ \frac{2e-2x}{e-a}, x \in (\frac{a+e}{2}, e] \\ 0, x \in (e, b] \end{cases} \tag{5}$$

(3) Good function

$$f_3(x) = \begin{cases} 0, x \in [a, c] \\ \frac{2x-2c}{b-c}, x \in (c, \frac{c+b}{2}] \\ \frac{2b-2x}{b-c}, x \in [\frac{c+b}{2}, b) \end{cases} \tag{6}$$

(4) Excellent function

$$f_4(x) = \begin{cases} 0, x \in [a, d] \\ \frac{x-d}{b+e-2d}, x \in (d, \frac{e+b}{2}] \\ 1, x \in (\frac{e+b}{2}, b] \end{cases} \tag{7}$$
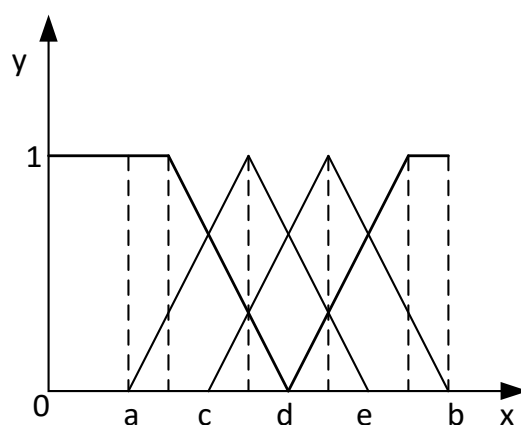
Figure 4. Triangular fuzzy membership function.

The fuzzy set $r_i = \{ r_{i1}, r_{i2}, \ldots, r_{im} \}$ can be constructed. r_{ij} represents the membership degree of the evaluation factor e_i to the graded fuzzy subset V_j. Combine the fuzzy subsets corresponding to each single benefit indicator to form an evaluation matrix:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \tag{8}$$

Step 8: Comprehensive evaluation of multiple benefit indicators.

Since the $M(\cdot, \oplus)$ operator can clearly reflect the role of the weight of each indicator, this paper selects the $M(\cdot, \oplus)$ operator for fuzzy transformation:

$$B = (b_1, b_2, \ldots, b_m) = A \circ R = (a_1, a_2, \ldots, a_n) \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \tag{9}$$

b_j is the membership degree of a large-scale energy storage project belonging to the j-th comment V_j when comprehensively considering the impact of all benefit indicators. *B* is a fuzzy set on the comment set V, and $\circ$ represents the $M(\cdot, \oplus)$ operator.

Step 9: Give the comprehensive evaluation conclusion.

According to the principle of maximum membership, compare the values of b_j in fuzzy set *B*, take the level corresponding to the largest b_j value, and determine the (excellent, good, qualified, unqualified) level corresponding to the large-scale energy storage project.

3. Results

Zhenjiang grid-side storage project located in Fangjin District. It is 101 MW capacity with 7524.4 million yuan total investment. Considered its operating lease business mode, the cost only needs to involve operating costs, and its recycle revenue cannot be included in the grid side revenue. Relevant original data was obtained through the project investigation.

3.1. Evaluation Indicators Values of Zhenjiang Storage Project

3.1.1. Energy Efficiency Indicators Values

The project uses lithium iron phosphate batteries. Through the latest research results of energy storage technologies [50], the original data for energy efficiency evaluation of energy storage systems is shown in Table 3.
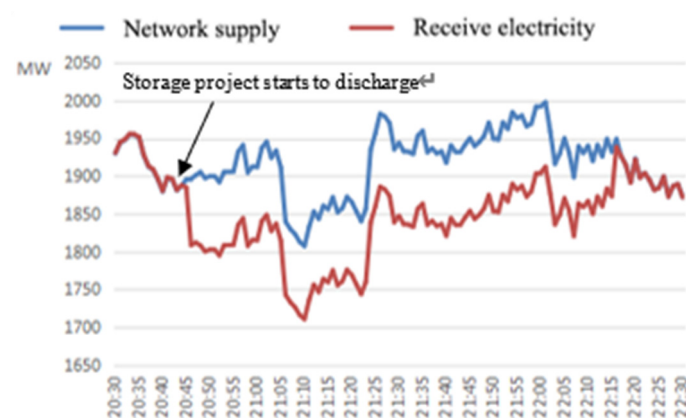
Table 3. Lithium iron phosphate energy efficiency data.

Indicator	A1	A2	A3	A4	A5	A6	A7	A8
Value	3.6	160	1200	1%	10,000	95%	7	9

3.1.2. Economic Indicators Values

Since the project was put into operation in July 2018, the Zhenjiang storage project has played a vital role in peak shifting and valley filling. During the peak summer period, a total of 157 charges and 149 discharges were completed, and the overall operating efficiency was about 85%. The peak-to-valley arbitrage benefit (B5) was calculated to be 18.325 million yuan based on the peak and valley electricity prices. The unit capacity saved cost on the grid side is 0.02 million yuan per MW [51], and the calculated saving investment (B6) is 6.267 million yuan. According to the energy data manual, the max line loss rate is 4.79% and the min line loss the rate is 3.59%, and B8 is calculated to be 69,700 yuan.

Take the maximum load day in Zhenjiang in 2018 as an example, the day load curve of the maximum load is shown in Figure 5. The discharge of the energy storage station caused the maximum power drop from 1997.56 MW to 1912.26 MW during this period. The policy subsidy value (B7) was calculated as 37.532 million yuan based on the subsidy of 440 yuan per kilowatt.

Figure 5. Load curve of the maximum load day in 2018.

3.1.3. Social and Environmental Indicators Values

In terms of grid reliability indicators, when the penetration rate of energy storage is 40% [52], the value of grid reliability indicators with or without energy storage is simulated as shown in Table 4. The scenario 1 is energy storage participated and scenario 2 is without storage. The calculated values of C_1 and C_2 are -0.028×10^{-5} and 2.79×10^{-7}.

Table 4. Reliability index value with or without the participation of energy storage.

Scenario	LOLP (%)	EENS (MWh $\times$ a^{-1})	BPECI (h $\times$ a^{-1})	ASAI (%)
1	3.2035×10^{-5}	34.5100	0.28063	99.9967965
2	3.2315×10^{-5}	34.8110	0.28308	99.9967686

LOLP: loss of load probability. EENS: Expected energy not supplied. BPECI: Bulk power energy curtailment index. ASAI: average service availability index.

In the tripping accident, the primary frequency modulation response with Zhenjiang storage power station is faster, and the time to reach the maximum adjustment is shorter compared with the conventional units. According to calculations, the contribution of the Zhenjiang side energy storage power station to the grid frequency modulation (C_3) is 50 times that of the thermal power unit of the same capacity as shown in Figure 6.
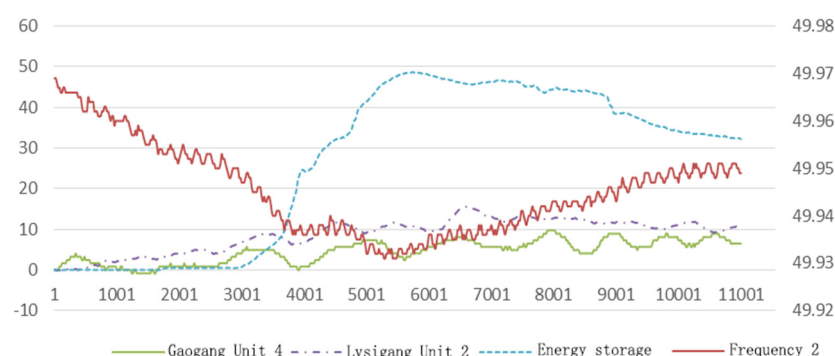
Figure 6. Contribution comparison of frequency regulation between energy storage and conventional unit.

Since the Zhenjiang energy storage was put into AGC in October 2018, the control performance standard (CPS) index of Jiangsu Power Grid has increased significantly compared with the same period last year. According to the calculation formula, C4 is 7.8%. The Jiangsu Power Grid CPS index from 2018 to 2018 is shown in Table 5:

Table 5. Jiangsu Power Grid CPS Index during 2015–2018.

Year	2015	2016	2017	2018
CPS	143.70	145.33	143.58	154.72

CPS: The CPS standard introduced by the North American Electric Reliability Council serves as the main index for the control of the power and frequency deviation of the grid tie line.

At the end of 2018, Jiangsu Power Grid has achieved full consumption of new energy for 13 consecutive years, and D1 is calculated to be 45.3%; based on the unit electric energy emission cost of thermal power units is 0.11 yuan/kWh, and the energy storage charge is 157 times, so that promote new energy accounted for a quarter of the total value of the year, the D2 is 2.943 million yuan, and the final revenue is 65.124 million yuan.

The lease period of the energy storage power station group is eight years, the annual lease fee is 6% of the annual income, and the lease fee is 3.907 million yuan. The total operation and maintenance costs can be calculated at 2% of the total investment. The operation and maintenance cost of the energy power plant group is calculated at a quarter of 700,000 yuan, while B4 is 4.607 million yuan.

3.2. Comprehensive Benefit Evaluation of Zhenjiang Storage Project

3.2.1. Index System Weight Determination

Through interviews with relevant experts from North China Electric Power University, NARI Group, State Grid Energy Research Institute, and Jiangsu Economic Research Institute, the influence of the two elements was established as shown in Table 6.

According to the obtained judgment matrix, a weighted hypermatrix is constructed. Part of the weighted super matrix is shown in Table 7.

In the process of weighted hypermatrix stability, calculate the limit relative ranking vector by calculating the limit of each hypermatrix, and get the final weight of each index. The final weight of some indicators is shown in Table 8.

Table 6. Influence relationship among indicators.

	A$_1$	A$_2$	A$_3$	A$_4$	A$_5$	A$_6$	A$_7$	A$_8$	B$_4$	B$_5$	B$_6$	B$_7$	B$_8$	C$_1$	C$_2$	C$_3$	C$_4$	D$_1$	D$_2$
A$_1$																			
A$_2$																			
A$_3$																			
A$_4$																			
A$_5$							√												
A$_6$				√															
A$_7$	√			√					√	√									
A$_8$																			
B$_4$	√	√	√	√	√		√	√				√							
B$_5$	√	√	√	√	√	√	√	√	√			√			√				
B$_6$	√	√	√	√	√	√	√	√	√	√					√				
B$_7$	√	√	√	√	√	√	√	√	√	√	√				√	√			
B$_8$	√	√	√	√	√	√	√	√	√	√	√				√				
C$_1$	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		
C$_2$	√	√	√	√	√	√	√	√	√	√	√			√		√			
C$_3$	√	√	√	√	√	√	√	√	√		√								
C$_4$	√	√	√	√	√	√	√	√	√		√					√			
D$_1$	√	√	√	√	√	√	√	√	√		√					√			
D$_2$	√	√	√	√	√	√	√	√	√	√	√		√			√		√	

Table 7. Part of weighted hypermatrix.

	A$_1$	A$_2$	A$_3$	A$_4$	A$_5$	A$_6$	A$_7$	A$_8$
A$_1$	0	0	0	0.18434	0	0	0	0
A$_2$	0.10917	0	0.05911	0.0742	0.13172	0.04176	0	0
A$_3$	0.16706	0.0477	0	0.03882	0.10387	0.05295	0	0
A$_4$	0.03874	0.02207	0.09557	0	0.06994	0.07936	0	0
A$_5$	0.03874	0.0163	0.03692	0.03882	0	0.11245	0.11682	0
A$_6$	0.03874	0.11602	0.026	0.05756	0.04935	0	0.35049	0
A$_7$	0.03874	0.13261	0.22391	0.03258	0.05621	0.09039	0	0
A$_8$	0.03612	0.13261	0.02579	0.04098	0.05621	0.09039	0	0
B$_4$	0.05168	0.03591	0.06221	0.05941	0.01352	0	0.04323	0.02853
B$_5$	0.03917	0.05664	0.03617	0.03839	0.0213	0.08035	0.01644	0.07141
B$_6$	0.02969	0.02884	0.02504	0.02761	0.03397	0.01342	0.0303	0.05393
B$_7$	0.0225	0.02196	0.01988	0.02	0.06553	0.0275	0.06029	0.03778
B$_8$	0.01705	0.01672	0.01678	0.01467	0.02577	0.03882	0.00983	0.10886
C$_1$	0.03827	0.05509	0.12704	0.07094	0.09103	0.05813	0.08401	0.07205
C$_2$	0.05412	0.16603	0.08014	0.15484	0.04663	0.16571	0.13497	0.03877
C$_3$	0.07654	0.03736	0.04803	0.03397	0.1063	0.03558	0.03865	0.27637
C$_4$	0.10824	0.0187	0.02196	0.01743	0.03322	0.01776	0.01955	0.13313
D$_1$	0.06362	0.06362	0.06362	0.03181	0.07158	0.02386	0.01909	0.14332
D$_2$	0.03181	0.03181	0.03181	0.06362	0.02386	0.07158	0.07635	0.03583

Table 8. Indicator weight after limit stability.

Indicator	D_2	C_3	C_4	B_4	B_7	B_8	A_6	A_7	A_8
Limiting	0.13744	0.007347	0.006773	0.007902	0.149637	0.081315	0.001145	0.00432	0.00011

3.2.2. Fuzzy Comprehensive Benefit Evaluation

The range of each indicator value is based on the actual operation of the project, literature, and calculations, and finally the comprehensive benefit evaluation model for the Zhenjiang large-scale energy storage project is established, as shown in Table 9.

Table 9. Comment set of Zhenjiang large-scale energy storage project.

Indicator	Excellent	Good	Qualified	Unqualified	Value
A_1	{3.25; 4}	{2.5; 3.25}	{1.75; 2.5}	{1; 1.75}	3.6
A_2	{200; 250}	{150; 200}	{100; 150}	{50; 100}	160
A_3	{1040; 1340}	{740; 1040}	{440; 740}	{140; 440}	1200
A_4	{0; 5%}	{5%; 10%}	{10%; 15%}	{15%; 20%}	1%
A_5	{12,000; 16,000}	{8000; 12,000}	{4000; 8000}	{0; 4000}	13,000
A_6	{95%; 100%}	{90%; 95%}	{85%; 90%}	{80%; 85%}	95%
A_7	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	7
A_8	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	9
B_4	{0; 326}	{326; 651}	{651; 977}	{977; 1304}	460.7
B_5	{1617.5; 2156.6}	{1078.3; 1617.5}	{539.2; 1078.3}	{0; 539.2}	1831.3
B_6	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	6
B_7	{3954; 5272}	{2636; 3954}	{1318; 2636}	{0; 1318}	3753.2
B_8	{6.93–9.24}	{4.62–6.93}	{2.31; 4.62}	{0; 2.31}	6.97
C_1	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	7
C_2	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	8
C_3	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	6
C_4	{7.5; 10}	{5; 7.5}	{2.5; 5}	{0; 2.5}	9
D_1	{0.45; 0.6}	{0.3; 0.45}	{0.15; 0.3}	{0; 0.15}	0.453
D_2	{246.6; 328.8}	{164.4; 246.6}	{82.2; 164.4}	{0; 82.2}	294.3

According to Formulas (4)–(7), the membership degree of each index is calculated. The final membership degree is calculated as {0.662306961, 0.500543371, 0.131011504, 0}. According to the principle of maximum membership degree, the comprehensive benefit level of the energy storage power station is excellent. According to the comprehensive evaluation results, the Zhenjiang energy storage power station group in Jiangsu Province has good benefits, which are consistent with the actual operation conditions. The result proves the effectiveness of the fuzzy comprehensive benefit evaluation model of the large-scale energy storage project built in this paper

4. Discussion

From the perspective of energy efficiency, lithium iron phosphate battery is the best choice for grid-side energy storage among the existing technologies. With the continuous improvement of new energy storage technologies, lithium iron phosphate battery may lose its advantages. The future development direction of lithium iron phosphate battery should make efforts to improve the stability performance.

As shown in Table 10, the highest revenue source of the energy storage project is government subsidy, which is 37.53 million yuan, accounting for almost two-thirds of the total revenue of 60.52 million yuan. Secondly, followed by peak and valley arbitrage, which is 18.31 million yuan. The highest indirect revenue from energy storage is delaying grid investment, followed by energy saving and emission reduction benefits, and the lowest revenue is reducing network losses. When considering the economics of energy storage, indirect revenue cannot be included in profitability, so the main profit comes from government subsidy and peak-to-valley arbitrage. However, with the advancement of power reform, large industrial power price has been reduced, peak-to-valley spread has narrowed, peak-to-valley arbitrage revenue will be greatly reduced, and government subsidy will become the main source of income. As a result, energy storage projects have poor economic benefits. In addition, the cost of electrochemical energy storage has slowed down in recent years, and even due to the improvement of safety performance, the investment cost has risen. In the non-lease mode, high investment costs and operating costs are potential problems for energy storage development.

Table 10. Economic analysis of Zhenjiang large-scale energy storage project.

	Indicator	Value (unit: million yuan)
Cost	B_4	4.61
Profit	B_5	18.31
	B_6	6.27
	B_7	37.53
	B_8	0.07
	D_2	2.94
Total revenue		60.52

From the perspective of social and environmental benefits, the commissioning of energy storage has increased the availability of system power supply by 0.3% and improved the power supply reliability of the entire power system. Not only that, the energy storage system has also promoted the consumption of new energy, and indirectly saved 2.943 million yuan in the emission cost of thermal power units, which has promoted the energy transition process to a certain extent.

As energy storage project technology is developing and business modes are still being explored, it is common that the grid-side energy storage projects are not profitable from the financial perspective. In this empirical analysis, the reward for permanent transfer of peak power load and the reward for temporarily reduce from demand response are 550 yuan/kW and 120 yuan/kW, which are the highest level of policy-based rewards. At the end of project cycle, the net present value is −315.88 million yuan, and the internal rate of return is less than 0. Although the grid-side energy storage projects have a large number of indirect benefits brought from social and environmental benefits, the real reflection of the energy storage projects' financial status deserves further attention.

The Fuzzy-ANP approach is comprehensible and effective for large and complex projects such as grid-side energy storage. This approach fully considers the subjective opinions of decision-makers and experts when determining the weights, which is necessary for the energy storage system from a growing insight. Because of the development of energy storage system, there would be lagging change of objective weight determination. The ANP method can well solve the problem by taking advantage of the instant grasp of industry information by experts and decision makers. Although the AHP method is simpler, it does not take into account the mutual influence among the indicators, which tends to bias the final decision result. Compared with giving specific values, this approach could bring a scriptable and actual result for decision maker. Through the case analysis, this approach show its effectiveness for the comprehensive benefit evaluation and it is worthy of being applied to other grid energy storage projects.

5. Conclusions

The comprehensive benefit evaluation system established in this article comprehensively covers four dimensions from energy efficiency, economy, social benefits, and environmental benefits. Compared with the financial evaluation, it is more in line with the actual situation of the grid-side energy storage project. Moreover, the index system takes into account the current relatively mature business modes, so it can be applied to four business modes after the selection of indicators, which is universal and applicable. The fuzzy comprehensive evaluation method and network analytic hierarchy process are introduced to reflect the interaction between indicators and evaluate the comprehensive benefits scientifically and quantitatively, which matches the development stage of the grid-side energy storage system at this stage. The evaluation level of the 100-MW storage project is excellent, which is consistent with the actual operation situation. Although large-scale energy storage projects are still faced with many obstacles in the receiving power grid, it has good comprehensive benefits in the power system according to the empirical results. Based on the results, the following suggestions are conducted for the development of grid side scale energy storage projects:

Multiple business modes would be developed in parallel to strengthen the commercial application of existing grid side. The existing projects operation mostly adopts the operating lease mode, while the return cycle is long. In the scientific planning of the scale and layout of energy storage, it is necessary to strengthen the exploration and optimization of the existing business modes of demonstration projects through the actual operation status data, in order to accumulate experience in the whole process of marketization.

The research and development investment should be increased to further reduce the cost of electrochemical energy storage and improve its safety. Promote the development of new energy storage technologies by encouraging technological innovation; create a fair market and improve the investment recovery mechanism of energy storage facilities; increase market vitality and attract multiple parties to participate in the industrialization development process of energy storage industry.

The relevance and necessity of storing energy included into the electricity price of transmission and distribution need fully discuss. Policy subsidies and peak-valley price difference are the main economic sources of large-scale energy storage application in the receiving end grid. Establish an electricity price linkage time-sharing mechanism of power supply side, power grid side and user side, and realize the application value of energy storage peak-valley arbitrage through price incentive. All parties would be encouraged to actively participate in energy saving and low-carbon life, so as to reduce the operating pressure caused by the big difference between peak and valley.

In future work, objective weight determination methods can be added to the weight determination, so that subjective and objective weights can be combined to reflect the relationship and difference between indicators more scientifically and comprehensively. In addition, considering the risk factors in the index system is worthy of further study.

Data Availability Statement: The numerical data used to support the findings of this study are included within the article.

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References

1. Essa, M.J.M.A. Power management of grid-integrated energy storage batteries with intermittent renewables. *J. Energy Storage* **2020**, *31*, 101762. [CrossRef]
2. Conlon, T.; Waite, M.; Modi, V. Assessing new transmission and energy storage in achieving increasing renewable generation targets in a regional grid. *Appl. Energy* **2019**, *250*, 1085–1098. [CrossRef]
3. Sheha, M.; Mohammadi, K.; Powell, K. Techno-economic analysis of the impact of dynamic electricity prices on solar penetration in a smart grid environment with distributed energy storage. *Appl. Energy* **2021**, *282*, 116168. [CrossRef]
4. Frate, G.F.; Ferrari, L.; Desideri, U. Energy storage for grid-scale applications: Technology review and economic feasibility analysis. *Renew. Energy* **2020**, *163*, 1754–1772. [CrossRef]
5. Zame, K.K.; Brehm, C.A.; Nitica, A.T.; Richard, C.L.; Schweitzer III, G.D. Smart grid and energy storage: Policy recommendations. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1646–1654. [CrossRef]
6. Barelli, L.; Bidini, G.; Ciupageanu, D.; Pelosi, D. Integrating Hybrid Energy Storage System on a Wind Generator to enhance grid safety and stability: A Levelized Cost of Electricity analysis. *J. Energy Storage* **2021**, *34*, 102050. [CrossRef]
7. Child, M.; Kemfert, C.; Bogdanov, D.; Breyer, C. Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe. *Renew. Energy* **2019**, *139*, 80–101. [CrossRef]
8. Schoenung, S.M.; Eyer, J.M.; Iannucci, J.J.; Horgan, S.A. Energy Storage for a Competitive Power Market. *Annu. Rev. Energy Environ.* **1996**, *21*, 347–370. [CrossRef]
9. Sioshansi, R.; Denholm, P.; Jenkin, T. Market and Policy Barriers to Deployment of Energy Storage. *Econ. Energy Environ. Policy* **2012**, 1. [CrossRef]
10. Li, J.L.; Wang, J.B.; Yuan X., D.; Zhou, J.H. A Review of Energy Storage Industry Policies. *Electr. Energy Manag. Technol.* **2019**, *20*, 1–9.
11. Valero, A.; Serra, L.; Uche, J. Fundamentals of Exergy Cost Accounting and Thermoeconomics. Part I: Theory. *J. Energy Resour. Technol.* **2005**, *128*, 1–8. [CrossRef]
12. Poonpun, P.; Jewell, W.T. Analysis of the Cost per Kilowatt Hour to Store Electricity. *IEEE Trans. Energy Convers.* **2008**, *23*, 529–534. [CrossRef]
13. Skyllas-Kazacos, M.; Menictas, C. The vanadium redox battery for emergency back-up application. In Proceedings of the 19th International Telecommunications Energy Conference—INTELEC 1997, Melbourne, VIC, Australia, 19–23 October 1997; IEEE: Piscataway, NJ, USA, 1997; pp. 463–471.
14. Sasaki, T.; Kadoya, T.; Enomoto, K. Study on load frequency control using Redox flow batteries. *IEEE Trans. Power Syst.* **2004**, *1*, 580–586.
15. Sedghi, M.; Ahmadian, A.; Aliakbar-Golkar, M. Optimal Storage Planning in Active Distribution Network Considering Uncertainty of Wind Power Distributed Generation. *IEEE Trans. Power Syst.* **2016**, *31*, 304–316. [CrossRef]
16. Nick, M.; Cherkaoui, R.; Paolone, M. Optimal Allocation of Dispersed Energy Storage Systems in Active Distribution Networks for Energy Balance and Grid Support. *IEEE Trans. Power Syst.* **2014**, *29*, 2300–2310. [CrossRef]
17. Yuan, J.; Luo, X.; Li, Z.; Li, L.; Ji, P.; Zhou, Q.; Zhang, Z. Sustainable development evaluation on wind power compressed air energy storage projects based on multi-source heterogeneous data. *Renew. Energy* **2021**, *169*, 1175–1189. [CrossRef]
18. Wu, Y.; Wu, C.; Zhou, J.; He, F.; Xu, C.; Zhang, B.; Zhang, T. An investment decision framework for photovoltaic power coupling hydrogen storage project based on a mixed evaluation method under intuitionistic fuzzy environment. *J. Energy Storage* **2020**, *30*, 101601. [CrossRef]
19. Liu, Y.; Zheng, R.; Chen, S.; Yuan, J. The economy of wind-integrated-energy-storage projects in China's upcoming power market: A real options approach. *Resour. Policy* **2019**, *63*, 101434. [CrossRef]
20. Wu, Y.; Xu, C.; Zhang, B.; Tao, Y.; Li, X.; Chu, H.; Liu, F. Sustainability performance assessment of wind power coupling hydrogen storage projects using a hybrid evaluation technique based on interval type-2 fuzzy set. *Energy* **2019**, *179*, 1176–1190. [CrossRef]
21. Sidhu, A.S.; Pollitt, M.G.; Anaya, K.L. A social cost benefit analysis of grid-scale electrical energy storage projects: A case study. *Appl. Energy* **2018**, *212*, 881–894. [CrossRef]
22. Ghadi, M.J.; Ghavidel, S.; Rajabi, A.; Azizivahed, A.; Li, L.; Zhang, J. A review on economic and technical operation of active distribution systems. *Renew. Sustain. Energy Rev.* **2019**, *104*, 38–53. [CrossRef]
23. Saboori, H.; Hemmati, R.; Ghiasi, S.M.S.; Dehghan, S. Energy storage planning in electric power distribution networks—A state-of-the-art review. *Renew. Sustain. Energy Rev.* **2017**, *79*, 1108–1121. [CrossRef]
24. Afzali, P.; Shoa, N.A.; Rashidinejad, M.; Bakhshai, A. Techno-economic study driven based on available efficiency index for optimal operation of a smart grid in the presence of energy storage system. *J. Energy Storage* **2020**, *32*, 101853. [CrossRef]
25. Colmenar-Santos, A.; Reino-Rio, C.; Borge-Diez, D.; Collado-Fernández, E. Distributed generation: A review of factors that can contribute most to achieve a scenario of DG units embedded in the new distribution networks. *Renew. Sustain. Energy Rev.* **2016**, *59*, 1130–1148. [CrossRef]
26. Escalera, A.; Hayes, B.; Prodanović, M. A survey of reliability assessment techniques for modern distribution networks. *Renew. Sustain. Energy Rev.* **2018**, *91*, 344–357. [CrossRef]

27. Parwal, A.; Fregelius, M.; Temiz, I.; Göteman, M.; De Oliveira, J.G.; Boström, C.; Leijon, M. Energy management for a grid-connected wave energy park through a hybrid energy storage system. *Appl. Energy* **2018**, *231*, 399–411. [CrossRef]

28. Mudumbai, R.; Dasgupta, S.; Cho, B.B. Distributed Control for Optimal Economic Dispatch of a Network of Heterogeneous Power Generators. *IEEE Trans. Power Syst.* **2012**, *27*, 1750–1760. [CrossRef]

29. Tang, C.; Xu, J.; Sun, Y.; Liu, J.; Li, X.; Ke, D.; Yang, J.; Peng, X. Look-Ahead Economic Dispatch With Adjustable Confidence Interval Based on a Truncated Versatile Distribution Model for Wind Power. *IEEE Trans. Power Syst.* **2018**, *33*, 1755–1767. [CrossRef]

30. Panda, D.K.; Das, S. Economic operational analytics for energy storage placement at different grid locations and contingency scenarios with stochastic wind profiles. *Renew. Sustain. Energy Rev.* **2021**, *137*, 110474. [CrossRef]

31. Wu, Y.N.; Zhang, T.; Zhong, K.; Wang, L.W.; Xu, C.; Xu, R. Optimal planning of energy storage technologies considering thirteen demand scenarios from the perspective of electricity Grid: A Three-Stage framework. *Energy Convers. Manag.* **2021**, *229*, 113789. [CrossRef]

32. National Energy Administrator: Interim Measures for the Management of Central Financial Incentive Funds for the Comprehensive Pilot Work of Electricity Demand Side Management. Available online: http://www.nea.gov.cn/2012-07/17/c_131719717.htm (accessed on 25 January 2021).

33. Liu, J.; Hu, C.; Kimber, A.; Wang, Z. Uses, Cost-Benefit Analysis, and Markets of Energy Storage Systems for Electric Grid Applications. *J. Energy Storage* **2020**, *32*, 101731. [CrossRef]

34. Wu, W.; Lin, B. Application value of energy storage in power grid: A special case of China electricity market. *Energy* **2018**, *165*, 1191–1199. [CrossRef]

35. Ding, J.; Xu, Y.; Chen, H.; Sun, W.; Hu, S.; Sun, S. Value and economic estimation model for grid-scale energy storage in monopoly power markets. *Appl. Energy* **2019**, *240*, 986–1002. [CrossRef]

36. Pupo-Roncallo, O.; Ingham, D.; Pourkashanian, M. Techno-economic benefits of grid-scale energy storage in future energy systems. *Energy Rep.* **2020**, *6*, 242–248. [CrossRef]

37. Hannan, M.; Al-Shetwi, A.; Begum, R.; Young, S.; Hoque, M.; Ker, P.; Mansur, M.; Alzaareer, K. The value of thermal management control strategies for battery energy storage in grid decarbonization: Issues and recommendations. *J. Clean. Prod.* **2020**, *276*, 124223. [CrossRef]

38. Arbabzadeh, M.; Johnson, J.X.; Keoleian, G.A. Parameters driving environmental performance of energy storage systems across grid applications. *J. Energy Storage* **2017**, *12*, 11–28. [CrossRef]

39. Hu, J.; Li, Q.H.; Huang, B.B.; Feng, K.H. Business Model Research of Energy Storage on Grid Side Adapted to Application Scenarios and Policy Environment in China. *J. Glob. Energy Interconnect.* **2019**, *2*, 367–375.

40. Li, J.C.; Li, J.Y.; Niu, D.X.; Wu, Y.N. Study on the evaluation model for the power grid corporation operation ability based on ANP. *Power Syst. Prot. Control* **2011**, *39*, 37–43.

41. Wu, L.P. Research on Fuzzy Comprehensive Evaluation Method and Its Application. 2006. Available online: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=2006152868.nh&DbName=CMFD2006 (accessed on 20 February 2021). (In Chinese)

42. Liu, S.; Du, S.X. Fuzzy comprehensive evaluation based on data envelopment analysis. *Fuzzy Syst. Math.* **2010**, *24*, 93–98.

43. Luo, C.; Ju, Y.; Gonzalez, E.D.S.; Dong, P.; Wang, A. The waste-to-energy incineration plant site selection based on hesitant fuzzy linguistic Best-Worst method ANP and double parameters TOPSIS approach: A case study in China. *Energy* **2020**, *211*, 118564. [CrossRef]

44. Ervural, B.C.; Zaim, S.; Demirel, O.F.; Aydin, Z.; Delen, D. An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey's energy planning. *Renew. Sustain. Energy Rev.* **2018**, *82*, 1538–1550. [CrossRef]

45. Wang, M.; Niu, D. Research on project post-evaluation of wind power based on improved ANP and fuzzy comprehensive evaluation model of trapezoid subordinate function improved by interval number. *Renew. Energy* **2019**, *132*, 255–265. [CrossRef]

46. Wu, Y.; Zhang, B.; Xu, C.; Li, L. Site selection decision framework using fuzzy ANP-VIKOR for large commercial rooftop PV system based on sustainability perspective. *Sustain. Cities Soc.* **2018**, *40*, 454–470. [CrossRef]

47. Wu, T.; Liu, S.; Ni, M.; Zhao, Y.; Shen, P.; Rafique, S.F. Model design and structure research for integration system of energy, information and transportation networks based on ANP-fuzzy comprehensive evaluation. *Glob. Energy Interconnect.* **2018**, *1*, 137–144.

48. Morteza, Z.; Reza, F.M.; Seddiq, M.M.; Sharareh, P.; Jamal, G. Selection of the optimal tourism site using the ANP and fuzzy TOPSIS in the framework of Integrated Coastal Zone Management: A case of Qeshm Island. *Ocean Coast. Manag.* **2016**, *130*, 179–187. [CrossRef]

49. Alilou, H.; Rahmati, O.; Singh, V.P.; Choubin, B.; Pradhan, B.; Keesstra, S.; Ghiasi, S.S.; Sadeghi, S.H. Evaluation of watershed health using Fuzzy-ANP approach considering geo-environmental and topo-hydrological criteria. *J. Environ. Manag.* **2019**, *232*, 22–36. [CrossRef] [PubMed]

50. Qian, Q.Q. Research on Comprehensive Evaluation of Energy Storage System Applied in Wind Farm. North China Electric University 2016. Available online: https://kns.cnki.net/kcms/detail/detail.aspx?FileName=1016267316.nh&DbName=CMFD2017 (accessed on 20 February 2021). (In Chinese)

51. Guo, L.; Xue, G.Y.; Wu, C.; Xie Z., J.; Liu, G.J.; Li, B.J. Research on economic evaluation of energy storage applied to load shift. *Power Demand Side Manag.* **2019**, *21*, 31–34.

52. Zhong, Y.F.; Huang, M.X.; Qiang, D.J. Reliability modeling of battery energy storage system and its effect on the reliability of distribution system. *Power Syst. Prot. Control* **2013**, *41*, 95–102.