Evaluation method of energy efficiency index of smart energy station based on subjective weight and entropy evaluation method

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Abstract. Smart energy station plays the pivotal role of power grid in energy collection, transmission, conversion and utilization due to its characteristics of multi-station integration. In order to accurately evaluate the energy efficiency level of smart energy stations and achieve economic and efficient electricity consumption, an energy efficiency evaluation system suitable for the form of three stations in one is proposed. Firstly, the influencing factors of energy consumption of each station are analyzed, the index system of smart energy stations is established, and the calculation method of each index is given. Secondly, based on the index system of energy efficiency, through the combination of the subjective weighting method and entropy evaluation method to determine the index weight, combined with the score and weight of energy efficiency for smart energy efficiency assessment, based on three different running environment of wisdom energy station simulation comparison, get the efficiency score, verify the feasibility of the assessment method, and gives specific suggestions on saving energy consumption.

Keywords: Three stations in one, Index system, Hierarchical analysis, Correlation analysis, The evaluation of energy efficiency.

1 Introduction

Power grid enterprises are exploring the integrated construction of substation, data center and energy station by utilizing advantages such as transformer resources, in order to form an intelligent energy saving intelligent energy station [1,2]. The use of substation site resources to establish distributed energy storage system becomes an important link of energy transmission and conversion utilization, and provides a basis for multi-energy collaboration. Energy storage stations can effectively participate in the regulation of regional power grid and delay the construction investment required to meet the short-term maximum load. Based on modular equipment and comprehensive energy efficiency management platform, data center station can make up for the shortage of cloud, realize the

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sub-center function of cloud data center, improve unit energy efficiency, reduce operation cost, and improve operation capacity.

Literature [3] proposes a comprehensive energy efficiency assessment method suitable for static, dynamic and technical and economic analysis of power grids. Literature [4] constructs the energy efficiency evaluation index system of substation from four perspectives: electrical equipment performance, system operating state, building structure performance and operating environmental factors. Literature [5] compares the energy efficiency difference between AC and DC power distribution schemes of optical storage and charging stations. It can be seen that at present, energy efficiency assessment methods in the field of electric power mainly stay at the level of traditional equipment. With the rise of smart energy stations, the energy efficiency evaluation system of smart energy stations is becoming more and more important.

2 Smart energy station and its energy efficiency index system

Smart energy station, which is based on new substation, innovating the mode of construction, substation, data center, energy storage station, electric vehicle in power stations, distributed new energy sources such as rooftop pv integration[6], achieve energy flow, data flow, business flow, to improve power grid comprehensive efficiency benefit, satisfy the requirement of the urban construction of energy, environment comprehensive[7-9]. In addition to the main transformer and station transformer used to transmit and supply electricity, the substation also has secondary equipment such as signal control device, dc power supply, relay protection and insulation monitoring, as well as auxiliary equipment such as cooling device and air conditioning [10,11]. The main energy consumption equipment is temperature and humidity regulating equipment such as cooling device and air conditioning. Comprehensive energy station includes photovoltaic system, energy storage system and charging pile and other equipment. The energy storage station is utilized to realize the effect of "peak shifting and valley filling", relieve the power supply pressure of the energy station, integrate the conventional secondary and communication equipment battery group of the substation and the UPS power supply of the data center, and provide standby DC power supply for the traditional secondary equipment and communication equipment. Among them, the conversion efficiency of lead battery and flow battery is low, about 70%-85%, while the conversion efficiency of lithium-ion battery is generally above 90%. Therefore, the conversion efficiency is a key factor affecting the energy efficiency of energy storage devices. In photovoltaic systems and charging stations, the loss of charging piles and grid-connected converters accounts for the largest proportion, accounting for more than 70% of the total loss, followed by line loss, which is due to the large number of branches of charging piles and the long transmission lines, so the loss proportion is large [12]. The energy consumption of a data center is considered from the following five aspects: power consumption of the base station main device, temperature and humidity control devices such as air conditioners, power supply system, other auxiliary devices, and equipment room construction. Among them, the energy consumption of the base station's main equipment and air conditioning accounted for more than 90% of the total energy consumption of the data center [13]. In addition, the AC/DC hybrid network provides DC power supply, and reuse energy storage as backup power supply.

By comprehensively considering the above factors affecting the energy consumption of the whole smart energy station and analyzing from five perspectives including substation, data center, energy station, building equipment and degree of automation of auxiliary equipment. a three-station integrated comprehensive energy efficiency evaluation system is established, as shown in Figure 1.

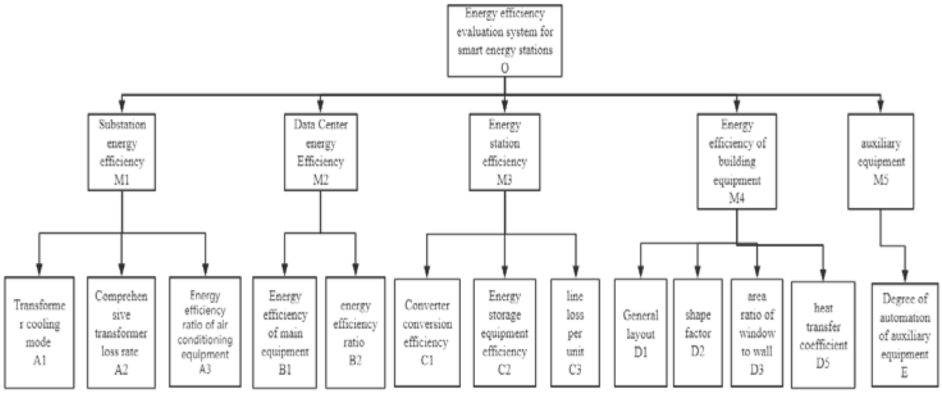

Fig. 1. AHP structure diagram of smart energy station.

3 Calculation method of energy efficiency index of smart energy station

3.1 Energy efficiency index of substation

3.1.1 Comprehensive transformer loss rate

The comprehensive loss of transformer mainly consists of the no-load loss of main transformer and station transformer, the active loss caused by the no-load current reactive loss, the load loss and the active loss caused by the leakage reactance flux leakage reactive loss of winding during load. If the reactive power economic equivalent, load fluctuation coefficient and transformer load coefficient are known, the comprehensive loss of the transformer can be expressed as [14]:

$$\Delta P = P_0 + K_Q Q_0 + K_T (P_k + K_Q Q_k)\beta^2 \tag{1}$$

where, P_0 is the no-load loss of the transformer, Q_0 is the magnetization power loss of the transformer, P_k is the rated load power loss of the transformer, and Q_k is the MFL power of the winding under the rated load of the transformer.

Then the loss rate of the transformer is:

$$\Delta P\% = \frac{\Delta P}{P_2 + \Delta P} \times 100\% = \frac{\Delta P}{\beta S_N \cos\varphi + \Delta P} \times 100\% \tag{2}$$

S_N Is the rated capacity of the transformer, $\cos\varphi$ is the average power factor of the transformer load side

3.1.2. Main transformer cooling mode

The main function of the cooling system is to cool the power equipment running for a long time. It is also an important power consumption equipment. The commonly used cooling methods of power transformers are generally divided into three kinds: oil-immersed self-cooling, oil-immersed air-cooling and forced oil circulation, and the forced oil circulation has two kinds of strong oil-air cooling and strong oil-water cooling. The forced oil circulation has more energy consumption due to the oil pump and fan, and the oil-immersed self-cooling type has less loss due to the lack of special cooling equipment. The total power consumed by the oil-immersed self-cooling type, oil-immersed air-cooling type and forced oil circulation is $P_{oilauto}$ $P_{oilwind}$ P_{foroil} respectively, Then the energy efficiency of the cooling equipment can be expressed as:

$$A_2 = \frac{1}{P_{油自} + P_{油风} + P_{强油}} (P_{油自}a_1 + P_{油风}a_2 + P_{强油}a_3) \tag{3}$$

Among them, A1, A2 and A3 are respectively the proportion of the number of oil-immersed self-cooling, oil-immersed air-cooling and forced oil circulation units to the total number of units.

3.1.3. Energy efficiency ratio of air conditioning equipment

Air conditioning system is a very important temperature regulating device, which is often used for refrigeration and cooling. Its energy consumption also accounts for a considerable part. At present, in order to save energy, most power stations have begun to adopt automatic regulating devices, and each air conditioning device has a standard energy efficiency ratio, That is, the ratio of cooling capacity and input power, so the energy efficiency ratio of air conditioning is introduced to measure the energy consumption of air conditioning equipment in the whole intelligent energy station. The calculation formula is as follows:

$$E_{ER} = \sum_{i=1}^{t} E_{ERi} \frac{P_{out.i}}{P_{out.total}} \tag{4}$$

where, t is the number of air conditioners, is the energy efficiency ratio of the ith air conditioner, is the cooling capacity of the ith air conditioner, and is the total rated cooling capacity of all air conditioners.

3.2 Data center energy efficiency indicators

3.2.1 Energy efficiency of main equipment

The power consumption of primary devices in a data center mainly includes carrier frequency power consumption and cabinet base power consumption. The basic energy consumption of the cabinet is mainly composed of the control board, fans and other devices, accounting for about 10% of the energy consumption of the main device. The number of carrier frequency is the main factor affecting the energy consumption of the main device, so the energy efficiency of the main device can be expressed by Equation (5)

$$B_1 = \frac{\sum_{i=1}^{s} P_{CFi}}{P_S} \tag{5}$$

where, P_{CFi} is the power consumption of the i^{th} carrier frequency; P_S is the total power of the power supply; S is the carrier frequency.

3.2.2 Energy efficiency ratio of air conditioning equipment

The calculation method of air conditioning energy efficiency is the same as that in the energy efficiency index of substation, which will not be repeated here.

3.3 Energy station efficiency indicators

As mentioned above, the main energy consumption influencing factors of comprehensive energy station are converter conversion efficiency, energy storage conversion efficiency and line loss rate.

3.3.1 Converter conversion efficiency

In energy stations, converters are essential. Energy storage equipment is connected to the AC power grid through AC/DC converter. Photovoltaic grid-connected and charging piles also need the use of converters. Therefore, the conversion efficiency of the converter C_1 is expressed by Equation (6):

$$C_1 = \frac{\sum_{i=1}^{b} \eta_i}{b} \tag{6}$$

where: b is the total number of converters; η_i is the efficiency of the inverter of the ith statio.

3.3.2 Energy storage equipment efficiency

Energy consumption of energy storage devices is mainly related to battery materials. The better the battery performance, the higher the energy storage conversion efficiency, which can be expressed by Formula (7):

$$C_2 = \frac{\sum_{j=1}^{c} E_j}{c} \tag{7}$$

where: c is the total number of converters; E_j is the conversion efficiency of the jth energy storage device.

3.3.3 Line loss per unit

The so-called line loss rate refers to the ratio of the electrical energy lost on the line to the electrical energy input at the beginning of the line. The power loss of the line can be obtained by the maximum power loss time method or the empirical method, and the line loss rate can be expressed as:

$$C_3 = \frac{\Delta W_z}{W_1} \times 100\% = \frac{\Delta W_z}{W_2 + \Delta W_z} \times 100\% \tag{8}$$

where, W_1 is the electrical energy input at the beginning of the line, and ΔW_z is the electrical energy loss on the line.

3.4 Energy efficiency of building equipment

Smart energy station there is a requirement for energy saving in building types mainly include personnel mainstream master communication and demand for the normal operation of the equipment has the thermal environment of the secondary equipment room, from the perspective of energy saving, considering the need to meet the winter cold and heat, as much as possible to get the sun radiation heat and reduce heat loss, at the same time should also take into account the summer heat, Comprehensive consideration is taken to achieve the purpose of energy saving [15]. The building factors that affect energy consumption mainly include general layout, building form and building envelope.

3.4.1 General layout

Total plane layout of buildings should be for the northern and southern dynasties, as far as possible to get more solar radiation during the winter, therefore, needs to have thermal environment of the equipment in the building, close to or down to 1 for the northern and southern dynasties, or down to 0, the sum of the number of buildings in the north and the south N_s and equipment construction combined with thermal environment needs the ratio of N to show layout efficiency:

$$D_1 = \frac{N_s}{N} \tag{9}$$

3.4.2 Shape factor

The size coefficient is the ratio of the surface area of the building in contact with the outside atmosphere to the volume surrounding it. Shape coefficient should be controlled within 0.3 as far as possible, it reflects the complexity of a building size and how many of the palisade structure heat dissipation area, the larger the shape coefficient, is the more complex shape, the greater its palisade structure heat dissipation area, the greater the building palisade structure heat transfer heat consumption, so the building shape coefficient is one of the important factors that affect building material consumptions heat index, its formula is:

$$S = \frac{F_0}{V_0} \tag{10}$$

where: S is the building size coefficient, F_0 is the building surface area, and V_0 is the building volume.

3.4.3 Area ratio of window to wall

The area ratio of each facing window to wall D_3 refers to the ratio of the total area S_{win} of each window, balcony door and transparent part of the curtain wall facing the outer wall to the total area S_{wall} of the building facing it. The thermal insulation performance of ordinary Windows is much worse than that of external walls. The larger the window wall area ratio is, the greater the energy consumption of heating and air conditioning is. Therefore, from the point of view of reducing building energy consumption, the window wall area ratio must be limited. National standard GB50189-2005 stipulates window wall area ratio should not be greater than 0.7.

$$D_3 = \frac{S_{win}}{S_{wall}} \tag{11}$$

3.4.4 Heat transfer coefficient

Usually from aspects of wall structure design and material selection, the heat preservation performance mainly reflected on the heat transfer coefficient, heat transfer from one side of palisade structure resistance to the other side are called palisade structure heat transfer resistance, national standard, according to different regions, not old wall area ratio have different heat transfer coefficient of limit value, the instance analysis can be based on factors such as region according to the national standard to consult the relevant limit values. Research shows that the reduction of the heat transfer coefficient of the external wall will significantly reduce the building energy consumption [16]. The heat transfer coefficient K is the reciprocal of the heat transfer resistance R_0 , i.e:

$$D_4 = K = \frac{1}{R_0} \tag{12}$$

3.5 Auxiliary equipment

Auxiliary equipment automation auxiliary equipment mainly includes some equipment, including lighting and secondary survey control, use large quantities because of the variety Distribution range is wide, so to evaluate its belong to automation equipment efficiency So the automation equipment of total power and the ratio of the total power of the total station auxiliary equipment to measure the energy efficiency of lighting, its expression is as follows:

$$\eta_L = \frac{\sum_{i=1}^{p} P_{es,i}}{\sum_{j=1}^{q} P_j} \tag{13}$$

where P is the number of energy-saving lamps and lanterns; Q is the number of all lighting equipment and $P_{es,i}$ is the total power of energy-saving lamps; P_j is the total power of the lighting equipment.

4 Energy efficiency assessment method for smart energy stations

4.1 Construct the analytic hierarchy process

Starting from the definition of energy consumption, the energy efficiency evaluation system of smart energy stations is established according to the principle of Analytic Hierarchy Process (AHP). The evaluation system is established with an emphasis on the equipment with energy saving space and the equipment with more energy consumption. The AHP model is divided into three layers [17]. The highest target layer is to improve the overall energy efficiency of smart energy stations. The middle is the criterion layer: M={energy efficiency of substation, data center, energy station, building equipment, lighting equipment}; The bottom layer is scheme layer N, which mainly contains some indicators of each criterion layer. Figure 1 shows the energy efficiency index system.

4.2 Standardization of index data

Indicators used to evaluate energy efficiency can be classified into extremely large indicators or extremely small indicators. Since the higher the energy efficiency, the better, the extremely small indicators can be converted into extremely large indicators. The conversion method is as follows:

$$y' = y_{\max} - y \tag{14}$$

where, ymax is the maximum value of very small index, y is the index value before conversion, and y' is the index value after conversion.

Let the change interval of the kth index be $[a,b]$, then the transformation formula of the k[th] index transforming into a dimensionless value is:

$$C_k = \frac{y_k - a}{b - a} \qquad k = 1, 2, ..., n \tag{15}$$

where: n is the number of indicators

4.3 Weight determination method

4.3.1 Subjective weight method

The method consists of the following two parts.

(1) Construct judgment matrix. According to the established index model, experts compare each index in pairs in each layer, assign corresponding weights to each index according to its relative importance, and construct the judgment matrix. In general, the constructed judgment matrix is shown in Table 1. The definition of the judgment matrix scale is shown in Table 2.

Table 1. Judgment matrix form.

B_k	C_1	C_2	$\cdots$	C_n
C_1	C_{11}	C_{12}	$\cdots$	C_{1n}
C_2	C_{21}	C_{22}	$\cdots$	C_{2n}
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
C_n	C_{n1}	C_{n2}	$\cdots$	C_{nn}

Table 2. Meaning of judgment matrix scale.

number	Importance level	C_{ij} valuation
1	i and j are equally important	1
2	i is slightly more important than j	3
3	i is obviously more important than j	5
4	i is strongly more important than j	7
5	i is strongly extremely more important than j	9

Annotation: $C_{ij} = 1/C_{ji}$, $C_{ij} = \left\{2,4,6,8,\frac{1}{2},\frac{1}{4},\frac{1}{6},\frac{1}{8}\right\}$ Indicates a level of importance between $C_{ij} = \left\{1,3,5,7,9,\frac{1}{1},\frac{1}{3},\frac{1}{5},\frac{1}{7},\frac{1}{9}\right\}$

(2) Consistency check

The consistency test is used to test the rationality of the judgment matrix. The negative mean value CI and the average random consistency index of the other characteristic roots other than the maximum characteristic root of the judgment matrix RI are introduced as the index to measure the deviation consistency of the judgment matrix, i.e

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{16}$$

$\lambda_{\max}$ and n are the maximum eigenvalue and order of the judgment matrix respectively.

$$CR = \frac{CI}{RI} \tag{17}$$

4.3.2 Entropy evaluation method

In information theory, entropy is a measure of uncertain information. The greater the amount of information, the smaller the uncertainty and the lower the entropy. The smaller the amount of information, the greater the uncertainty, the greater the entropy, that is, the greater the impact of the index on the comprehensive evaluation. Since the normalization method has been mentioned in 3.2, it will not be mentioned here. The steps for calculating the entropy value are as follows:

(1) Calculate the specific gravity of the JTH index of the ith object

$$Y_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{18}$$

(2) Calculate the index information entropy

$$e_j = -k\sum_{i=1}^{m}(Y_{ij} * \ln Y_{ij}) \tag{19}$$

(3) The information entropy redundancy is calculated

$$d_j = 1 - e_j \tag{20}$$

(4) Calculation of index weight

$$W_i = d_j / \sum_{j=1}^{n} d_j \tag{21}$$

(5) Single object evaluation score is calculated

$$S_{ij} = W_i * X_{ij} \tag{22}$$

In the formula, X_{ij} represents the value of the jth evaluation index of the ith object, $k = 1/\ln m$, where m is the number of evaluation objects and n is the number of indicators.

4.3.3 Determination of comprehensive weight

The above sections introduce two methods to determine weight, namely subjective weight method and correlation degree analysis method. The subjective weight method can fully absorb the knowledge and experience of experts in the field, but its shortcoming is that it has too strong subjective consciousness, and it is not entirely reasonable to use subjective weight as the evaluation weight. The correlation degree analysis is to calculate the correlation degree between the actual data and the ideal data. The greater the correlation degree, the greater the influence degree. However, in this case, the use of the correlation degree analysis could not reflect the easy improvement degree of energy efficiency. Therefore, a comprehensive weight can be obtained by combining the subjective weight method and the correlation degree analysis method with the weighted method to draw on each other's strengths and make up for each other's weaknesses, i.e:

$$b_k = \frac{x_k + a_k}{2} \quad k = 1, 2, ..., m \tag{23}$$

b_k is the comprehensive weight, x_k is subjective weight, m is the number of indicators.

4.4 Evaluation score calculation

Through the above analysis, the score value and weight of each index have been calculated, so the index evaluation score of the upper layer is calculated as follows:

$$C_i = \sum_{k=1}^{n} W_k^{\ i} C_k^{\ i} \quad i = 1, 2, ..., m \tag{24}$$

$W_k^{\ i}$ is the weight of the kth index under the ith index of the criterion layer, $C_k^{\ i}$ is the score value of the kth index under the ith index of the criterion layer, C_i is the score of the ith index of the criterion layer.

5 Simulated analysis

With 3 different smart energy stations A and B C as an example, assess the efficiency of three power station, power station after standardization of original data and the maximum data as shown in table 3, based on the above proposed evaluation method, first of all, according to the index of the judgment matrix that subjective weight, according to the entropy value method to determine the objective weight, get the n-tier synthesis weights, the combination of three wisdom energy station after processing data, get M layer efficiency score, and then, According to the weight determination method of N layer, the weight of M layer is determined, and the energy efficiency score of M and N layer is finally calculated, as shown in Table 4. The index score of O layer and M layer of each energy station is shown in Table 5 As can be seen from the table, among the three energy stations, A is the most energy-efficient with an energy efficiency value of 0.7019, B is the second with an energy efficiency of 0.6227, and C is the worst with an energy efficiency of 0.6421 The energy efficiency score of the data center decreases. The energy efficiency of the four sub-level indicators decreases by 0.1-0.2 on average, and the total energy efficiency score decreases by about 0.06. Compared with A, energy efficiency of dynamic operation indexes such as substation energy station decreased by 0.1-0.2 on average, and the total energy efficiency decreased by nearly 0.08 percentage points. Meanwhile, it can also be seen from the weight that substation Energy station such as the weight of is higher, this is due to equipment such as photovoltaic and charging pile in standing, so there are a large number of inverter and line, therefore, to increase energy efficiency can be emphatically on the aspects to improve, reduce the loss .

In addition, to verify the validity of the method for determining weights, this paper based on the subjective weighting method and entropy value method, for smart energy station B A The energy efficiency of C has been analyzed twice, and the energy efficiency of all smart energy stations has been obtained. As shown in Table 6 and Table 7, the results obtained by the entropy method to determine the weight are different from those obtained by the subjective weight method, but basically belong to the same level, which shows the effectiveness of the objective weight method When the sample size of experts is insufficient or the opinions of experts differ greatly, the role of objective weight method can be reflected. Combining the two methods can obtain an accurate and effective method without losing bias.

Table 3. Data of smart energy stations.

N-tier indicators	A(before processing)	A(after processing)	B(before processing)	B(after processing)	C(before processing)	C(after processing)	Theoretic-al maximum
Comprehensive transformer loss rate	0.03	0.6	0.02	0.4	0.03	0.6	0.05
Main transformer cooling mode	0.75	0.75	0.6	0.6	0.75	0.75	1
energy efficiency ratio	3.2	0.64	3.2	0.64	3	0.6	5
Energy efficiency of main equipment	0.9	0.9	0.9	0.9	0.8	0.8	1
energy efficiency ratio	3.5	0.7	3.5	0.7	3	0.6	5
Converter conversion efficiency	0.9	0.9	0.8	0.8	0.9	0.9	1
Efficiency of energy storage equipment	0.94	0.94	0.82	0.82	0.94	0.94	1
line loss per unit	0.0586	0.414	0.07	0.3	0.0586	0.414	0.1
General layout	0.8	0.8	0.8	0.8	0.6	0.6	1
shape factor	0.8	0.8	0.8	0.8	0.6	0.6	1
area ratio of window to wall	0.4	0.6	0.4	0.6	0.5	0.5	1
heat transfer coefficient	0.46	0.54	0.46	0.54	0.6	0.4	1
energy-saving efficiency	0.9	0.9	0.9	0.9	0.7	0.7	1

Table 4. M. N-layer index weight.

M level	M layer comprehensive weight	M layer subjective weight	M layer correlation degree method weight	N-tier indicators	N layers of comprehensive weight	N layers of subjective weights	N layer correlation degree method weight
M1	0.4385	0.5299	0.347	A1	0.4255	0.1085	0.7425
				A2	0.2907	0.3445	0.2369
				A3	0.28375	0.5469	0.0206
M2	0.0971	0.1346	0.0596	B1	0.31035	0.25	0.3707
				B2	0.68965	0.75	0.6293
M3	0.2063	0.2443	0.1683	C1	0.33785	0.5695	0.1062
				C2	0.2376	0.3331	0.1421
				C3	0.42455	0.0974	0.7517
M4	0.1465	0.0589	0.2341	D1	0.1781	0.0703	0.2859
				D2	0.2048	0.1237	0.2859
				D3	0.1773	0.2364	0.1182
				D4	0.43985	0.5697	0.31
M5	0.1116	0.0323	0.1909	E	1	1	1

Table 5. O-layer and M-layer score based on comprehensive weight method.

Energy efficiency score of layer M	A	B	C
M1	0.6549	0.6665	0.6665
M2	0.7621	0.7552	0.6886
M3	0.7032	0.8367	0.7367
M4	0.6502	0.4671	0.5897
M5	0.9	0.9	0.7
O-layer energy efficiency score	0.7019	0.6227	0.6421

Table 6. O layer and M layer score based on subjective weight method.

Energy efficiency score of layer M	A	B	C
M1	0.673491	0.600116	0.651615
M2	0.75	0.75	0.65
M3	0.8659876	0.757962	0.86599
M4	0.604678	0.60468	0.46248
M5	0.9	0.9	0.7
O-layer energy efficiency score	0.7341	0.6688	0.6942

Table 7. O-layer and M-layer score based on entropy evaluation method.

Energy efficiency score of layer M	A	B	C
M1	0.6364	0.4515	0.6364
M2	0.7741	0.7741	0.6741
M3	0.5043	0.427	0.5043
M4	0.6958	0.6958	0.5262
M5	0.9	0.9	0.7
O-layer energy efficiency score	0.6927	0.6094	0.6088

6 Conclusion

There are many factors and different principles to consider in energy efficiency assessment. This paper mainly considers how to reduce energy consumption and completes the following contents:

(1) This paper introduces the specific structure and important components of smart energy station, analyzes the factors affecting energy consumption of substation, data center and energy station, and extracts the main energy consumption equipment with large power consumption.

(2) An energy efficiency index system based on "three stations in one form" is proposed for the intelligent energy station which integrates substation, data center and energy station.

(3) Based on the energy efficiency index framework, the analytic hierarchy process is improved and the weight is determined by entropy method, so as to establish the energy efficiency evaluation system of smart energy stations.

(4) Through the experimental calculation, the energy efficiency score of the smart energy station is obtained, the influence of different operating conditions on the energy efficiency is analyzed, and according to the data analysis, the aspects that need to be improved in the next step are pointed out, so as to provide a reference for energy saving scheme of the smart energy station.

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Reference

1. Xu Yong, Chen Hong, Luo Yi. Exploration of the application of intelligent energy station under the ubiquitous power Internet of things [J]. Public power, 2019, 34(08): 7-8.
2. Chen Xi, Fu Wei, Ji Qingchuan, et al. Research on comprehensive benefit measurement system of comprehensive energy service project [J]. Hunan electric power, 2019, 39(06): 5-8.

3. Fu Kexin, Peng Peng, Kong Jing, et al. Research on energy efficiency evaluation method of transmission network based on analytic hierarchy process [J]. Electrical measurement & instrumentation, 2016, 53(3): 23-26.
4. Luo Zhikun, Liu Xiaoxiao, Chen Xingying, et al. Power automation equipment, 2017, 37(03): 132-138.
5. Zhang Hua, Zhou Bo, JIANG Keteng, et al. Journal of Electric Power Systems and Automation, 2020:1-10.
6. Wang Ding, Shenyang Wu, Shao Zhu, et al. Quantitative analysis of key influencing factors of New energy consumption in Hunan Power Grid [J]. Hunan Electric Power, 201, 41(02): 65-69.
7. Gao Lin, cheng long, zhang cong, et al. Quantitative analysis of key influencing factors of new energy consumption in hunan power grid [J]. Hunan electric power, 2021, 41(02): 65-69.
8. He Yin-guo, WU Shu-sheng, Wen Ming, et al.Multi-objective Cooperative economic Dispatch considering SVC and Energy Storage Connected to power grid [J]. Hunan Electric Power, 2019, 41(2): 1-8, 14.
9. Chen jia, Chen huoyan, wen Ming, et al. Prediction of medium and long term power demand in hunan province [J]. Hunan electric power, 2018, 38(06): 20-24.
10. Zhao xiaodong, li feng, fu leilei, et al. Analysis of total factor energy efficiency of provincial industry from the perspective of low-carbon economy [J]. Hunan electric power, 2018, 38(01): 5-10.
11. Li Chunxia, ZHAO Xiangguang, LU Jinduo, et al. Study on Fuzzy Comprehensive Evaluation Method of Secondary Equipment Efficiency in Smart Substation [J]. Electrotechnical Technology, 2020(11): 136-139.
12. Lei yi, zhang hua, Zhou bo, et al. Comparative analysis of energy efficiency standards of distribution transformer [J]. Transformer, 2020, 57(05): 57-61.
13. Lu Rudong, Liu Lei, Liao Min. Comparison of energy efficiency of AC and DC power distribution in optical storage and Charging stations [J]. Journal of Electrical Systems and Automation, 2020.
14. Zhang Xingxing. Research on Energy Efficiency Evaluation Method and Application of power grid Equipment [D]. Hunan University, 2016.
15. ZHU Xianfeng, LI Luping, Yin Xiaobo, et al. Research on energy Efficiency Evaluation method and Application of power grid Equipment [D]. Hunan University, 2016.
16. Nie Jianchun, Zhang Zhen, Zhang Xiaoyan, et al. Energy saving design of substation building in Inner Mongolia [J]. Inner Mongolia electric power technology, 2018, 36(06): 43-46.
17. Du Dong. Pang qinghua. Wu yan. Modern comprehensive evaluation method and case selection [M]. Beijing: Tsinghua university press, 2015, 15 -- 24.