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Dynamic Comprehensive Evaluation of a 660MW Ultra-Supercritical Coal-Fired Unit Based on Improved Criteria Importance Through Inter-criteria Correlation and Entropy Weight Method

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Abstract: To address the issue of traditional static evaluation models being unable to comprehensively analyse the performance of ultra-supercritical coal-fired units under varying loads, we propose a dynamic comprehensive evaluation model based on the improved Criteria Importance Through Inter-criteria Correlation (CRITIC) method and Entropy Weight Method (EWM). The comprehensive performance evaluation index system of ultra-supercritical coal fired units is constructed by examining the boiler performance, turbine performance, plant power performance, environmental performance, and flexible performance of coal powered units. The CRITIC and EWM methods are used to calculate the weights of the indicators, which are then combined with the static evaluation results. Using a dynamic comprehensive evaluation model, we analysed ultra-supercritical coal-fired units, taking into account time weight. This allowed us to obtain the comprehensive dynamic real-time evaluation value of the units under different loads. The research indicates that the dynamic comprehensive evaluation model, which uses an improved CRITIC and EWM, has significant advantages in improving evaluation accuracy, weight-balanced distribution, and generality. Provides more accurate, reasonable, and reliable evaluation results for practical decision making.

Keywords: ultra-supercritical coal-fired units; dynamic comprehensive evaluation; evaluation index system; improved criteria importance though intercrieria correlation; entropy weight method

1. Introduction

As global climate change and pollution continue to worsen, countries have set carbon-neutral and dual-carbon targets to drive the transformation of the energy industry towards a more sustainable direction [1]. As an important part of traditional energy, the development and reform of coal-fired units under the background of dual carbon is particularly important [2]. In recent years, with increasing environmental concerns and the rise of clean energy, the comprehensive assessment of coal-fired units has become increasingly important [3]. In recent years, the comprehensive performance evaluation methods of coal-fired power plants have emerged, and many scholars at home and abroad have proposed a variety of comprehensive evaluation methods, such as analytical hierarchy process, entropy weight method, rank-sum ratio comprehensive evaluation method and fuzzy comprehensive evaluation method [4]. Ma et al. [5] proposed a comprehensive dynamic performance evaluation method to comprehensively understand the overall performance of coal-fired units under load changes, and to provide a basis for future optimization and improvement. Chen et al. [6] used fuzzy analytical hierarchy process and improved criteria importance through intercriteria correlation (CRITIC) to empower evaluation indicators, which reflected the rationality of comprehensive evaluation indicators and the effectiveness of evaluation methods. Wang et al. [7] determined the weights of the evaluation indicators by combining the entropy weighting method (EWM) and the subjective weighting method to achieve a comprehensive evaluation of the flexibility of coal-fired units. Huang et al. [8] analysed the distribution characteristics of carbon emissions from buildings across six aspects and provided recommendations for development. Wang et al. [9] assessed the long-term operational status of near-zero emission coal-fired units. Ma et al. [?] established the assessment framework of source-network-load interaction to provide a set of systematic indicators and methods for low-carbon development of coal-fired units and a more sustainable development path for coal-fired power plants. Comprehensive evaluation can be divided into static comprehensive evaluation and dynamic comprehensive evaluation [11]. In the static comprehensive evaluation, the evaluation object is evaluated comprehensively in a single period based on the information of each index of the evaluation object [11]. Dynamic comprehensive evaluation uses the same evaluation method to perform static comprehensive evaluation of evaluation objects at different time periods, and integrates with information aggregation operators to obtain the dynamic comprehensive evaluation value of evaluation objects [12]. At present, many scholars are paying attention to dynamic comprehensive evaluation. In 2007, Guo et al. [13] first proposed two types of information aggregation operators that can be used for dynamic comprehensive evaluation. On this basis, Li et al. [14] proposed a series of dynamic comprehensive evaluation methods based on the technique for order preference by similarity to ideal solution. Wang et al. [15] built an evaluation index system of the basic emergency response capability of the power grid based on the analysis of time and space dimensions, in order to achieve a dynamic and comprehensive evaluation of the emergency response capability of the power grid. Zhang et al. [16] proposed a new dynamic comprehensive evaluation model of multi-source uncertainty indicators based on the generalised grey incentive factors, and proved the effectiveness and feasibility of the model in combination with practical cases. This paper aims to solve the problem that the traditional static evaluation model cannot analyze the comprehensive performance of ultra-supercritical coal-fired units under varying loads. The evaluation index system for ultra-supercritical coal-fired units was constructed using the entropy weight method and the improved CRITIC method to determine the static weights of each index. A dynamic comprehensive evaluation model was then created by combining the time-series three-dimensional data table. On the basis of ensuring the accuracy, reliability and rationality of the evaluation results, the key indicators affecting the performance of coal-fired units are explored.

2. The construction of index system

2.1. Principle of index system construction

Coal-fired units are an extremely complex energy consumption system, combined with the economic and environmental benefits of the development of coal-fired units, the index system includes all aspects of the characteristics of the development of coal-fired units under the dual-carbon target, and can reflect the development characteristics of coal-fired units under the low-carbon target. Therefore, the index system should be based on the following construction principles [17]:

The principle of independence: the degree of coupling between the primary index and the secondary index of the index system should be chosen to be low, and redundancy, cross-information and noise between indicators should be reduced.

Operability principle: the selection of indicators should be easy to quantify, the data source should be reliable and easy to measure, collect and obtain, and it should ensure that the indicator data can be processed in a standardised way.

Completeness principle: the selection of evaluation indicators should be able to reflect the characteristics and connotation of the overall performance of coal-fired units in a comprehensive, multifaceted and accurate manner. When selecting evaluation indicators, special attention should be paid to the selection of qualitative and quantitative indicators.

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Objectivity principle: in the selection of indicators, the selected indicators can truly and accurately reflect the objectivity of the evaluation object, without complicating subjective factors, so as to make a fair and impartial comprehensive evaluation of the evaluation object.

Dynamic principle: the index system is a dynamically changing process in the selection process. Therefore, the dynamic change of indicators over time should be fully considered in the selection of indicators. Horizontal comparison indicators should be selected with a clear trend of change in order to differentiate, so as to avoid the selection of no change or small changes in the data.

2.2. Index system of coal-fired units

The evaluation criteria for coal-fired units are based on current national standards, relevant industry regulations, current management standards and methods of various Group companies, and local processes [18]. According to the selection principle of the evaluation index system, through the feasibility analysis of the initial index, combined with the actual situation of the site, the main factors of the coal-fired power plant are decomposed layer by layer, and the evaluation index system of the comprehensive performance of the coal-fired power plant is constructed, including 5 first-level evaluation indicators and 23 second-level evaluation indicators. Figure 1 shows the comprehensive evaluation index system of coal-fired units.

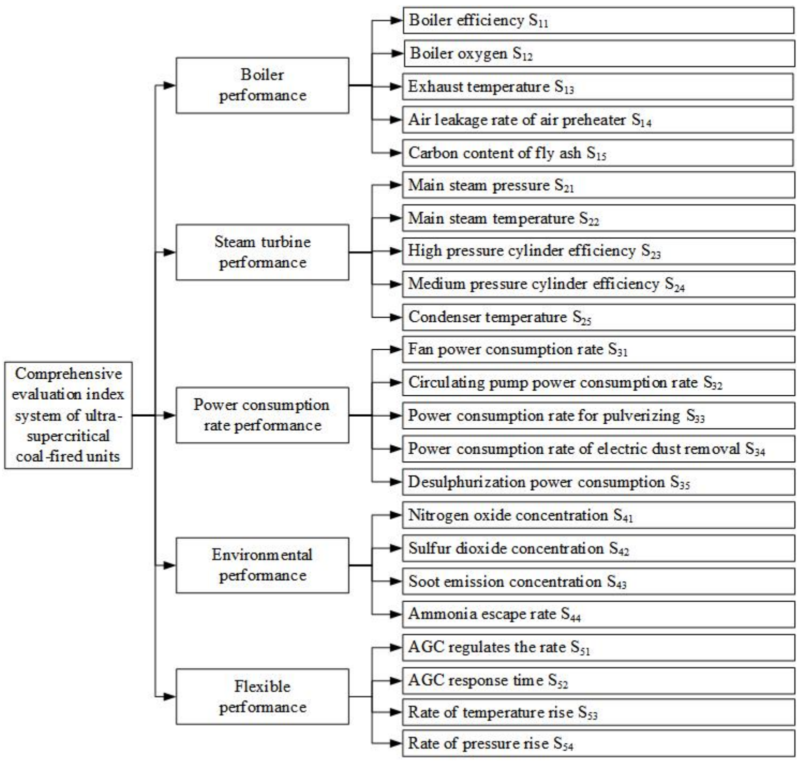

Figure 1. Comprehensive evaluation index system of coal-fired units

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3. Methods

3.1. Improve CRITIC method

Criteria Importance Through Intercrieria Correlation (CRITIC) [6] is an objective weighting method based on data volatility, and considers the comparative strength of evaluation indicators and the principle of conflict to comprehensively measure the objective weights between indicators.

To address issues with determining evaluation index weights in the original CRITIC, this paper introduces the concept of information entropy to improve the method, resulting in ICRITIC. The original CRITIC method has problems in calculating indicator weights, mainly due to the excessive weight of indicators caused by direct attribute assignment and correlation between indicators. This issue affects the accuracy and fairness of evaluation results.

ICRITIC is highly objective and versatile, allowing for a comprehensive reflection of the relationship between evaluation indicators. It also avoids any potential bias towards certain indicators that may be present in other methods. In practical applications, the ICRITIC method proposed in this paper provides a more accurate, reasonable, and reliable way to determine the weight of evaluation indicators.

Step 1: select m evaluation indications for n evaluation objects, establish the evaluation indicator system, construct the level matrix and standardize the processing.

Step 2: the variability of the evaluation index

$$\left\{\begin{array}{l} \bar{x}_j = \frac{1}{m}\sum\limits_{i=1}^{m} x_{ij} \\ S_j = \sqrt{\frac{\sum\limits_{i=1}^{m}\left(x_{ij}-\bar{x}_j\right)^2}{m-1}} \end{array}\right. ,\left(1 \le i \le m, 1 \le j \le n\right), \tag{1}$$

In the formula, x_{ij} is the evaluation matrix of each index, S_j is the standard deviation of the evaluation index.

Step 3: the conflict of evaluation indicators

$$R_j = \sum_{i=1}^{m}\left(1-\left|r_{ij}\right|\right), \left(1 \le i \le m, 1 \le j \le n\right) \tag{2}$$

In the formula, R_j is the conflict of evaluation index.

Step 4: information of evaluation indicators

$$\left\{\begin{array}{l} p_{ij} = \frac{x'_{ij}}{\sum\limits_{j=1}^{n} x'_{ij}} \\ E_j = -\frac{1}{\ln m}\sum\limits_{i=1}^{m} p_{ij}\ln p_{ij} \\ C_j = \left(E_j + \frac{S_j}{\bar{x}_j}\right) \times R_j \end{array}\right. ,\left(1 \le i \le m, 1 \le j \le n\right), \tag{3}$$

In the formula, p_{ij} is the characteristic of evaluation index, E_j is the information entropy of evaluation index, C_j is the information content of evaluation index.

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Step 5: objective weights of evaluation indicators

$$w'_j = \frac{C_j}{\sum\limits_{j=1}^{n} C_j}, (1 \le j \le n) \tag{4}$$

In the formula, w'_j is the weight of evaluation index.

3.2. Entropy weight method

Entropy weight method (EWM) [18,19] is an objective weighting method. The weight of each index's entropy is calculated based on its dispersion, and the weight of the objective index is then determined.

Step 1: The original data matrix composed of m evaluation objects and n evaluation indicators is denoted as $X = (x_{ij})_{m \times n}$.

Step 2: data normalization processing

$$\begin{cases} x'_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \\ x'_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \end{cases}, (1 \le i \le m, 1 \le j \le n), \tag{5}$$

In the formula, x'_{ij} is the standardised value of the evaluation indicators (without negative indicators).

Step 3: characteristic proportion of evaluation index

$$f_{ij} = x'_{ij} \Big/ \sum_{j=1}^{n} x'_{ij}, (1 \le i \le m, 1 \le j \le n) \tag{6}$$

In the formula, f_{ij} is the characteristic of evaluation index.

Step 4: the information entropy of evaluation index

$$H_j = -\frac{1}{\ln m} \sum_{i=1}^{m} f_{ij} \ln f_{ij}, (1 \le i \le m, 1 \le j \le n) \tag{7}$$

In the formula, H_j is the information entropy of evaluation index.

Step 5: objective weights of evaluation indicators

$$w_j = \frac{1 - H_j}{\sum\limits_{j=1}^{n} (1 - H_j)},, (1 \le j \le n) \tag{8}$$

In the formula, w_j is the weight of evaluation index.

3.3. Combinatorial weighting

In order to avoid an accident in the calculation process and the neglect of indicators by objective assignment, the overall weight is as close as possible to the objective weight, taking into account the advantages of each objective weight assignment. This paper adopts the minimum information entropy principle to synthesize the index weights obtained by ICRITIC and EWM. The Lagrange multiplier method is then used to optimize and obtain the comprehensive weights[20,21].

$$W_j^{CW} = \frac{\sqrt{W_j^{CRITIC} * W_j^{EWM}}}{\sum_{j=1}^{n} \sqrt{W_j^{CRITIC} * W_j^{EWM}}} \tag{9}$$

In the formula, W_j^{CW} is the combined weight of the evaluation index, W_j^{CRITIC} is the weight of the evaluation index calculated by CRITIC, W_j^{EWM} is the weight of the evaluation index calculated by EWM.

3.4. Aggregation operator

In 1998, Yager proposed the ordered weighted average (OWA) operator [22,23], which is an aggregation method of multi-attribute decision information between the maximum and minimum operators. Later, Guo et al. [13] proposed time ordered weighted averaging (TOWA) operator and time ordered weighted geometric averaging (TOWGA) operator.

3.4.1. TOWA operator

Let $N = \{1, 2, \cdots, n\}$, $\langle u_i, a_i \rangle$ is TOWA pair, where u_i is the time-induced component and a_i is the data component.

$$F(\langle u_1, a_1 \rangle, \cdots, \langle u_p, a_p \rangle) = \sum_{j=1}^{p} \lambda_j b_j \tag{10}$$

In the formula, vectors $\lambda = (\lambda_1, \lambda_2, \cdots, \lambda_p)^T$ and vectors $\vec{F}$ are related weighted vectors, $\lambda_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda_j = 1$. b_j represents the second component of the TOWA operator corresponding to time j, so the function is called an n-dimensional TOWA operator.

3.4.2. TOWGA operator

Let $N = \{1, 2, \cdots, n\}$, $\langle v_i, c_i \rangle$ is TOWA pair, where v_i is the time-induced component and c_i is the data component.

$$G(\langle v_1, c_1 \rangle, \cdots, \langle v_p, c_p \rangle) = \prod_{j=1}^{p} d_j^{\lambda'_j} \tag{11}$$

In the formula, vectors $\lambda' = (\lambda'_1, \lambda'_2, \cdots, \lambda'_p)^T$ and vectors $\vec{G}$ are related weighted vectors, $\lambda'_j \in [0,1]$ and $\sum_{j=1}^{n} \lambda'_j = 1$. d_j represents the second component of the TOWA operator corresponding to time j, so the function is called an n-dimensional TOWA operator.

3.4.3. TOWA-TOWGA hybrid model

According to the definition of aggregation operators, TOWA operators care about functionality and TOWGA operators care about balance, both have advantages and disadvantages [24] . Therefore, based on the static evaluation results and considering the influence of the time factor, the TOWA-TOWGA hybrid model is used to perform a dynamic comprehensive evaluation of the performance of ultra-supercritical coal-fired units.

$$Y_i = \alpha_1 F(\lambda_t) + \alpha_2 G(\lambda_t) \tag{12}$$

In the formula, α_1 and α_2 are the proportion of TOWA and TOWGA operators respectively, $0 \le \alpha_1 \le 1$, $0 \le \alpha_2 \le 1$, $\alpha_1 + \alpha_2 = 1$.

3.5. Determination of time weight

In dynamic comprehensive evaluation, time weighting reflects the relative importance of the evaluation object in different time periods in the process of information aggregation. Therefore, both subjective and objective factors need to be fully considered when determining time weights. On the one hand, the knowledge and experts experience should be taken into account, and on the other hand, objective information from time samples should be taken into account [13]. For the solution of the time weight, it is necessary to have a definition of the "time degree":

$$\theta = \sum_{t=1}^{p} \frac{p-t}{p-1} \lambda_t \tag{13}$$

In the formula, θ is the time degree, λ_t is the time weight vector.

Table 1 shows the value of "time degree" reflects the importance of time series to operators in the process of aggregation. When θ approaches 0, it indicates that the decision maker is paying more attention to the data in the most recent period. When θ approaches 1, it indicates that the decision maker pays more attention to data in the distant time period. When θ is the tent threshold with a value of 0.5, it indicates that the decision maker attaches the same importance to the sample information in each time period.

Table 1. Scale reference table for "time degree".

θ	**Significance**
0.1	Great emphasis on recent data
0.3	Pay more attention to recent data
0.5	Also focus on period data
0.7	Pay more attention to the forward data
0.9	Great emphasis on forward data
0.2 , 0.4 , 0.6 , 0.8	The intermediate case corresponding to the above two adjacent judgments

Under the condition of determining the "time degree", the programming method is used to determine the time weight. Through in-depth mining of sample information and comprehensive consideration of the relative importance of the evaluation object in different time periods, the time weight vector of the sample is clarified. Calculate the weight coefficient according to the variance formula[13]:

$$D^2(\lambda) = \sum_{i=1}^{p} \frac{1}{p} [\lambda_t - E(\lambda)]^2 = \frac{1}{p} \sum_{i=1}^{p} \lambda_t^2 - \frac{1}{p^2} \tag{14}$$

In the formula, $D^2(\lambda)$ is the variance, $E(\lambda)$ is the mean value of the time weight coefficient. TTherefore, the least variance method is used to solve the nonlinear programming problem[13]:

$$\begin{cases} \min \left(\frac{1}{p} \sum_{i=1}^{p} \lambda_t^2 - \frac{1}{p^2} \right) \\ st. \begin{cases} \theta = \sum_{=1}^{n} \frac{p-t}{p-1} \lambda_t \\ \sum_{t=1}^{p} \lambda_t = 1 \end{cases} \\ \lambda_t \in [0,1] \\ t = 1, 2, \cdots, n \end{cases} \tag{15}$$

4. Results and discussion

Based on the consultation of experts and the combination of the actual situation of the site, this paper takes the operating data of a 660MW coal-fired unit in Xinjiang from February 2023 to August

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2023 as the research object. The operating data with a stable operating time of more than 1 hour and a load variation range within ±2% have been selected for the analysis. At the same time, the variable working condition data with load variation range between 25% and 98%, excluding the selected stable operation data, is analysed based on the three sets of data selected in this paper. Due to the influence of environmental factors in the summer, turbine heat acceptance (THA) does not operate at 100% heat consumption during operation. Therefore, this paper selects data from summer 90%THA coal-fired units for comparative analysis.

4.1. Determination of combinatorial weights

The combined weights of evaluation indicators were obtained based on the objective weight data obtained by ICRITIC and EWM. Table 2 and Table 3 respectively show the combined weights of different evaluation indicators for the coal-fired units in different environments, where T_1 to T_6 represent February, March, April, June, July and August respectively.

Table 2. Static evaluation results in winter.

Index	100%THA(±2%)			50%THA(±2%)			Variable load(25%-98%)		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
S_{11}	0.0080	0.0122	0.0111	0.0226	0.0254	0.0161	0.0205	0.0144	0.0099
S_{12}	0.6344	0.6577	0.6244	0.6474	0.6134	0.5613	0.7631	0.7522	0.7143
S_{13}	0.1462	0.1058	0.1195	0.1131	0.1376	0.1803	0.0908	0.0915	0.0943
S_{14}	0.2113	0.2243	0.2449	0.2169	0.2236	0.2423	0.1256	0.1420	0.1816
S_{15}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_{21}	0.2178	0.1807	0.0830	0.3461	0.3281	0.2949	0.6262	0.5593	0.6110
S_{22}	0.1716	0.1429	0.0471	0.2073	0.1359	0.1073	0.0524	0.0474	0.0302
S_{23}	0.1518	0.1213	0.0710	0.1932	0.1636	0.1493	0.0882	0.0859	0.0708
S_{24}	0.0350	0.0256	0.0168	0.0417	0.0249	0.0240	0.0781	0.0662	0.0632
S_{25}	0.4237	0.5295	0.7821	0.2117	0.3475	0.4244	0.1552	0.2412	0.2248
S_{31}	0.0976	0.0713	0.0870	0.0472	0.0231	0.0264	0.1275	0.1198	0.1096
S_{32}	0.0292	0.0240	0.2759	0.0282	0.6038	0.5370	0.2553	0.3535	0.4052
S_{33}	0.1199	0.0725	0.0982	0.2486	0.0969	0.0953	0.1034	0.0862	0.0782
S_{34}	0.2855	0.2772	0.2270	0.3037	0.1224	0.1547	0.2230	0.1937	0.1885
S_{35}	0.4677	0.5551	0.3119	0.3723	0.1537	0.1866	0.2908	0.2468	0.2185
S_{41}	0.1166	0.1037	0.1366	0.2312	0.1556	0.1950	0.1580	0.1775	0.1903
S_{42}	0.4714	0.4768	0.3200	0.2962	0.3261	0.2028	0.4656	0.3767	0.2849
S_{43}	0.1274	0.2200	0.2714	0.0740	0.1633	0.1767	0.0983	0.1230	0.1615
S_{44}	0.2846	0.1995	0.2720	0.3986	0.3550	0.4255	0.2780	0.3228	0.3634
S_{51}	0.0715	0.2632	0.1142	0.2029	0.2231	0.1665	0.1055	0.1226	0.1252
S_{52}	0.8677	0.6324	0.7506	0.5780	0.6750	0.6754	0.7611	0.7779	0.7718
S_{53}	0.0280	0.0375	0.0718	0.0921	0.0392	0.0613	0.0452	0.0359	0.0384
S_{54}	0.0328	0.0669	0.0635	0.1270	0.0628	0.0968	0.0882	0.0635	0.0646

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Table 3. Static evaluation results in summer.

Index	90%THA(±2%)			50%THA(±2%)			Variable load(25%-98%)		
	T_4	T_5	T_6	T_4	T_5	T_6	T_4	T_5	T_6
S_{11}	0.0094	0.0063	0.0094	0.0124	0.0130	0.0142	0.0126	0.0071	0.0073
S_{12}	0.5838	0.6621	0.5509	0.4771	0.5025	0.5046	0.8002	0.7027	0.6911
S_{13}	0.1255	0.1180	0.1371	0.1695	0.1651	0.1645	0.0701	0.0813	0.0848
S_{14}	0.2813	0.2135	0.3026	0.3410	0.3194	0.3167	0.1170	0.2089	0.2169
S_{15}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_{21}	0.1477	0.1583	0.1712	0.2646	0.1734	0.2239	0.5009	0.4394	0.4787
S_{22}	0.0388	0.1104	0.0909	0.0519	0.0640	0.0488	0.0365	0.0485	0.0332
S_{23}	0.1113	0.1569	0.1253	0.1448	0.1203	0.1415	0.0920	0.0957	0.0921
S_{24}	0.0183	0.0174	0.0229	0.0216	0.0285	0.0276	0.0717	0.0432	0.0495
S_{25}	0.6839	0.5571	0.5897	0.5171	0.6138	0.5582	0.2988	0.3732	0.3464
S_{31}	0.0920	0.1074	0.0135	0.0501	0.0741	0.0054	0.1269	0.0853	0.0138
S_{32}	0.2497	0.1461	0.3647	0.4825	0.2762	0.4340	0.2992	0.3067	0.4155
S_{33}	0.1117	0.1728	0.3859	0.1700	0.2238	0.4969	0.0704	0.1087	0.4496
S_{34}	0.2487	0.3178	0.1110	0.0833	0.1474	0.0298	0.1841	0.2189	0.0549
S_{35}	0.2979	0.2558	0.1249	0.2142	0.2785	0.0340	0.3194	0.2803	0.0662
S_{41}	0.1127	0.0819	0.0767	0.1517	0.1315	0.1628	0.1354	0.1211	0.2295
S_{42}	0.3424	0.3073	0.3340	0.2378	0.1697	0.2359	0.3122	0.2631	0.2521
S_{43}	0.3108	0.4462	0.3592	0.2205	0.3837	0.2845	0.2837	0.3846	0.2985
S_{44}	0.2342	0.1647	0.2300	0.3900	0.3151	0.3168	0.2687	0.2312	0.2199
S_{51}	0.1622	0.2897	0.1186	0.2748	0.1181	0.0921	0.1380	0.0795	0.0795
S_{52}	0.7328	0.5992	0.6849	0.6139	0.7710	0.7752	0.7646	0.7977	0.8362
S_{53}	0.0522	0.0420	0.0965	0.0445	0.0331	0.0411	0.0295	0.0294	0.0211
S_{54}	0.0528	0.0691	0.1001	0.0669	0.0777	0.0915	0.0680	0.0935	0.0632

According to Figure 2 and Figure 3, to evaluate the effectiveness of ICRITIC, we tested and calculated the weight of evaluation indicators and compared it with CRITIC before the improvement. The comparison results indicate that the improved ICRITIC can eliminate any unjustified weight bias present in the original method. This leads to a more accurate evaluation of index weight and a more objective and comprehensive assessment.

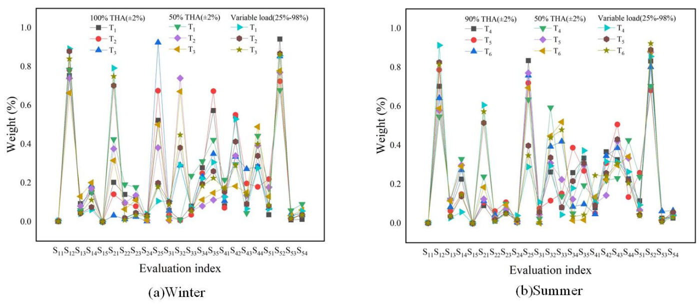

Figure 2. The indicators' combined weights are determined using the CRITIC in various environments.

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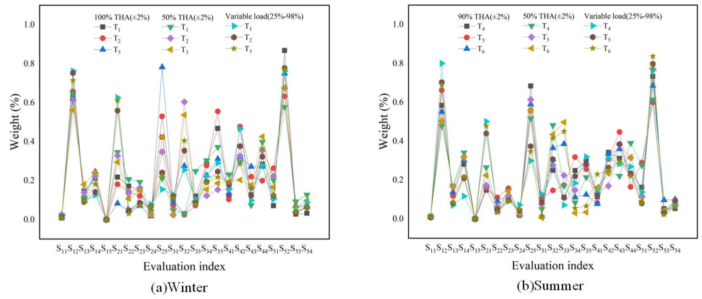

Figure 3. The indicators' combined weights are determined using the ICRITIC in various environments.

4.2. Determination of combinatorial weights

According to the advice of relevant experts, when θ is the tent threshold with a value of 0.3 and solve the programming equation with minimum variance to obtain the time weight vector:

$$\lambda = \begin{bmatrix} 0.1333 & 0.3333 & 0.5333 \end{bmatrix}$$

The static assessment results of each index are aggregated over time to produce the dynamic comprehensive assessment of the index. Where α_1 and α_2 are the tent threshold with a value of 0.5. Tab. 4 shows the final evaluation results of each indicator.

According to Table 4 and Figure 4, analysis of evaluation results under different circumstances:

From the boiler performance, the load of coal-fired units fluctuates greatly in summer and winter, and the load change can lead to the adjustment of system parameters that affect the performance of boiler oxygen and the air preheater. The temperature difference between summer and winter is large, causing the air heater to be affected by the temperature change and thus affecting the air leakage rate of the air heater.

Table 4. Results of dynamic comprehensive evaluation.

Index	Winter			Summer		
	100%THA (±2%)	**50%THA (±2%)**	**Variable load (25%-98%)**	**90%THA (±2%)**	**50%THA (±2%)**	**Variable load (25%-98%)**
S_{11}	0.0110	0.0198	0.0126	0.0083	0.0136	0.0079
S_{12}	0.6367	0.5897	0.7333	0.5913	0.5002	0.7091
S_{13}	0.1182	0.1560	0.0929	0.1290	0.1654	0.0816
S_{14}	0.2334	0.2326	0.1601	0.2684	0.3208	0.1991
S_{15}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
S_{21}	0.1279	0.3125	0.5955	0.1637	0.2114	0.4683
S_{22}	0.0883	0.1285	0.0383	0.0885	0.0541	0.0384
S_{23}	0.0962	0.1596	0.0780	0.1335	0.1347	0.0933
S_{24}	0.0217	0.0264	0.0661	0.0204	0.0270	0.0500
S_{25}	0.6415	0.3661	0.2200	0.5908	0.5708	0.3486
S_{31}	0.0829	0.0277	0.1153	0.0450	0.0258	0.0434
S_{32}	0.1248	0.4342	0.3660	0.2661	0.3832	0.3616
S_{33}	0.0918	0.1126	0.0840	0.2643	0.3462	0.2521
S_{34}	0.2508	0.1602	0.1947	0.1869	0.0672	0.1145
S_{35}	0.4063	0.1961	0.2370	0.1849	0.1136	0.1517
S_{41}	0.1225	0.1859	0.1816	0.0829	0.1505	0.1768
S_{42}	0.3887	0.2531	0.3367	0.3261	0.2128	0.2634
S_{43}	0.2319	0.1559	0.1391	0.3802	0.3064	0.3239
S_{44}	0.2481	0.3978	0.3378	0.2075	0.3256	0.2299
S_{51}	0.1499	0.1893	0.1216	0.1740	0.1204	0.0864
S_{52}	0.7248	0.6618	0.7724	0.6619	0.7512	0.8136
S_{53}	0.0528	0.0569	0.0384	0.0699	0.0388	0.0248
S_{54}	0.0599	0.0882	0.0672	0.0823	0.0834	0.0733

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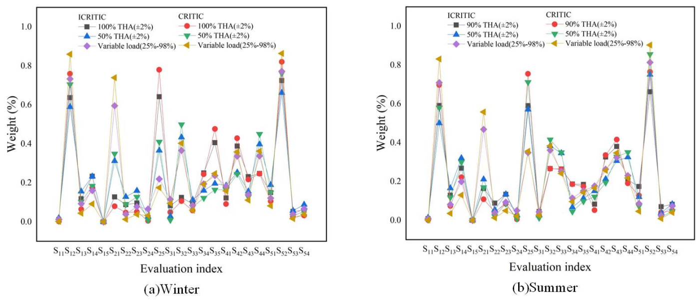

Figure 4. The indicators' combined weights are determined using the ICRITIC in various environments.

From the steam turbine performance, under different operating conditions in summer and winter, coal-fired units need to adjust the running state of the steam turbines to meet the needs of the power grid. The main steam pressure increases in weight while the condenser temperature decreases slightly due to load variation. The change in load will result in a change in steam properties which will have an effect on the operating condition of the condenser. In summer, when the ambient temperature is higher, the temperature of the cooling water may rise, causing the temperature of the condenser to increase. Although the ambient temperature is lower in winter, the temperature of the cooling water can still be higher.

From the power consumption rate performance, under varying operating conditions in different seasons, the circulating pump may require the use of valves or frequency conversion speed regulation to adjust the flow rate. This can cause the operating point of the circulating pump to deviate from the design condition, resulting in decreased pump efficiency. These factors can lead to an increase in power consumption of the circulating pump. During winter operation at 100% THA (±2%), the amount of coal burned increases, resulting in a corresponding increase in SO_2 emissions from flue gas. To comply with stringent environmental emission standards, the quantity of desulfurizer will be increased, resulting in higher power consumption of the desulfurization system.

From the environmental performance, the combustion system experiences varying load conditions during summer and winter operations, which can result in combustion process instability. The desulfurization system's performance has been reduced, and the flue gas is now contaminated with incompletely combusted pulverized coal and particulate matter. This results in an increase in SO_2 concentration, which in turn leads to higher rates of ammonia escape and smoke emissions.

From the flexibility performance, the coal-fired units will adjust their load instantly based on the power system's demand during different load operations in summer and winter. Automatic generation control (AGC) must respond quickly to these changes to ensure the frequency stability of the frequency of the power system, so as to meet the requirements of the power system and ensure the quality and reliability of the power supply.

According to the comparison of the improved critic, it can be seen that the improved method can more fully reflect the relationship between evaluation indicators, avoid undue weight bias that may occur in the original method, make the weights more balanced and stable, and thus improve the accuracy of indicator weights.

5. Conclusions

In order to analyse the change in overall performance of a 660 MW ultra-supercritical coal-fired unit in Xinjiang under varying operating conditions, a dynamic overall evaluation model based on an ICRITIC-EWM is proposed in this paper. The ICRITIC-EWM is used to improve the objective accuracy of static weights, and the TOWA-TOWGA mixed operator model is combined to aggregate the evaluation process of coal-fired units in the time dimension, so as to realise the dynamic comprehensive evaluation of coal-fired units under changing operating conditions.

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1. First item;This paper proposes a dynamic comprehensive evaluation model based on ICRITIC-EWM. The model aims to make the static weights of each evaluation index more objective, enabling efficient and accurate determination of the static weight parameters of coal-fired units.
2. Based on the actual running data of the power plant and the power plant performance assessment model in this paper, and analyzes the five comprehensive performances of the object power plant. Figure 4 and Table 4 show the different factors that affect the performance level of a power plant. shows the different factors that can affect the performance level of a power plant. These include the air leakage rate of the air preheater, condenser temperature, desulfurization power consumption rate, circulating pump power consumption rate, SO_2 concentration, dust emission concentration, ammonia escape rate, and AGC response time. It is important for the operator of the power plant to consider these factors when aiming to improve the plant's performance.
3. Most power plants do not conduct a comprehensive performance analysis for variable load conditions due to the lack of resources or expertise. Thus, this paper proposes using a dynamic and comprehensive evaluation model based on ICRITIC-EWM to obtain power plant operating state evaluation results at variable load. Furthermore, it is essential to conduct additional research on how to integrate the control system to establish a closed-loop regulation in the practical application of the power plant. This will enable the power plant to be automatically adjusted to achieve optimal operating conditions.

Author Contributions: H.Y. established a dynamic comprehensive evaluation model and verified it. M.X. established a dynamic comprehensive evaluation model. M.X. corrected the manuscript and put forward many suggestions for improvement. Z.C. put forward some suggestions when building the model, and analyzed the evaluation results. T.K. cexamined and revised the paper's model. All authors have read and agreed to the published version of the manuscript.

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