Thermal Performance Analysis Of Steam Power Plant Based On Exergy Criteria

Omar J Khaleel, Firas B Ismail, Thamir K Ibrahim

Abstract: Based on the basic theory of thermal equilibrium analysis, the equivalent heat drop method is used to summarize simple and effective algorithms for the equivalent heat drop of extraction steam at all levels. In this paper, exergy analysis method is theoretically studied and modeled, and the exergy matrix equation is established. The exergy analysis method based on the second law of thermodynamics is studied and modeled, and the exergy matrix equation is derived. The main contents include: the overall analysis and partial quantitative analysis of the thermal system of the unit from the perspective of thermal equilibrium analysis, the exergy analysis of the thermal system under variable operating conditions from the perspective of exergy analysis, to find out the system's defects and deficiencies. Analyze the exergy loss distribution rules and causes of thermal systems, find the weak links in the system, and make scientific explanations for various calculation indicators.

Index Terms: Thermal system, equivalent thermal drop method, exergy matrix equation, exergy analysis, structural optimization

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1. INTRODUCTION

Due to the influence and constraints of the primary energy structure and other factors, the proportion of steam power generation in the power industry has become increasingly tight. The steam power industry is a veritable energy consumer and also large energy consuming household with a relatively low level of energy efficiency [1, 2]. In recent years' energy-saving industry has begun to rise, but generally there is a problem of lagging development in energy-saving industry [3-5]. Due to difficulties in financing energy-saving technological transformation of enterprises and too little investment in research and development of energy-saving technologies, many key technologies and equipment rely on imports. The method of structural optimization of the thermal system can be mathematically optimized, and the sub-systems and thermal equipment and their parameters are optimized one by one, which is commonly known as the system engineering method and thermal equipment and their parameters one by one, which is commonly known as the classic optimization method [2, 6-9]. In [8, 9] they studied the structural optimization of the thermal system of the unit. Its optimized quantitative calculation and analysis are based on the equivalent heat drop method [10], while reference [11] applies the exergy analysis method to the 600MW thermal power unit for the first time. The thermal system was analyzed and optimized, and the exergy analysis software was compiled based on the actual project. In current thermal system analysis of power plants, the main analysis methods are: small index analysis method, thermal deviation method, equivalent steam extraction method, equivalent heat drop method, and circular function method [12]. These methods are based on the first law of thermodynamics as based on the analysis of unit economics from the perspective of energy quantity, it has been widely used due to its clear concepts, easy to understand, and easy to use [13-15]. It also has many successful experiences, but due to the use of traditional thermal balance methods, it does not consider the energy of different grades. The difference in "quality" places too much emphasis on the loss of the steam turbine cycle and condensers, and does not pay enough attention to the thermodynamic integrity of the boiler system [3, 16-18]. So, it is often possible to draw unreasonable conclusions, thereby optimizing the operation of the power plant and saving energy technical transformation into misleading; and analytical methods based on the first and second laws of thermodynamics, such as exergy analysis, entropy analysis, and thermoeconomic analysis, etc., take into account both the "quantity" and "quality" of energy. In the face of these realistic problems, it is urgently required to make efforts in the technical transformation of existing units and tap the energy-saving potential. This paper analyzes the exergy analysis of the second law of thermodynamics for the unit's thermal system to improve the unit's economy and bring the unit's indicators close to design Level, reaching or exceeding the level of similar domestic units. Comprehensively consider factors such as design, manufacturing, installation, operation and maintenance, optimize and improve the thermal system and its equipment for the thermal system of the unit, improve the operation and efficiency of the operation, and achieve the goal of energy saving, which is important for the development of power companies significance.

2. BACKGROUND

2.1 Exergy analysis method

The exergy analysis method based on the first and second laws of thermodynamics takes into account both the quantity and quality of energy, and can be used to easily calculate the irreversibility and thermodynamic integrity of various equipment or processes when used in the analysis of thermal systems in power plants [19]. The weak link of low energy utilization efficiency in the system was found, and the analysis results have guiding significance for the operation optimization of power plants and the energy-saving technical reform [17, 20]. Exergy analysis can also be used to make a realistic evaluation of the current status of the unit equipment, that is, to diagnose the energy saving of the equipment, and to determine the energy saving potential of each equipment and subsystem according to its deviation from the design conditions, which can be used as an improvement Guidance on equipment economics. At present, analysis using exergy analysis methods in actual power plants is still rare. One of the reasons is that exergy analysis concepts and theories are not easily accepted by enterprises. In order to provide exergy analysis as a basis for practical guidance, it is necessary to use exergy analysis. The analysis combines the practical application of power plants as the background to carry out the application research of exergy analysis methods. The current development of computers and their general application in power plants provide the possibility of exergy analysis for practically operating power plants, and the reform of the power enterprise system has also put forward urgent requirements for exergy analysis of power plants.

2.2 Exergy value calculation method

In the exergy analysis of the thermal system of a power plant [12], it mainly involved the calculation of the exergy of the enthalpy of the open system. The enthalpy exergy of an open system is the exergy of a stable material flow, which can be defined as: when a stable material flow flows from any given state through an open system to a reversible transition to an environmental state and only exchanges heat with the environment. The maximum useful work that can be done is called enthalpy exergy, and the calculation formula is [21].

$$e = h - h_0 - T_0(s - s_0) \tag{1}$$

Where h_0,T_0,and s_0 are the enthalpy, temperature, and entropy of the environmental state, respectively.

The stable flow through the heater of the power plant's regenerative system is water or water vapor. The specific exergy under the conditions of pressure P and temperature T can be calculated according to Eq. (1). Some water and water vapor thermodynamic properties tables include not only specific enthalpy h, specific entropy s, specific volume v, but also specific exergy e, which can be found directly from the relevant charts according to known states P, T (and x).

The exergy calculation formula of the fuel [22] is:

$$e_f = \Delta h_{u,l} + \gamma w \tag{2}$$

Where, $\Delta h_{u,l}$, is the low calorific value of the fuel, w is the moisture content of the fuel working fluid, and γ is the latent heat of vaporization of water at ambient temperature.

$$D_f = \frac{D_0 h_0 + D_{zrr} h_{zrr} - D_{gs} h_{gs} - D_{zrl} h_{zrl} - D_{gr} h_{gr}}{\eta_B \Delta h_{u,l}} \tag{3}$$

Where, ηB is the thermal efficiency of the boiler, and the average value of the thermal balance test is 93.76%. D0, and Dzr are the main steam and reheat steam flows, Dgs, and Dgr are the feed water and super-heater desuper-heating water flows, and Df is the total fuel consumption. , h0, and hgs are the superheated steam and feed water enthalpy, hzrr, and hzrl are the reheater outlet and inlet enthalpy, and hgr is the superheated steam spray water cooling enthalpy.

$$E_f = G_f e_f \tag{4}$$

2.3 General model and equilibrium equation for exergy analysis

The general model for engineering exergy analysis is a complete all-round analysis model composed of exergy flow that can fully meet the engineering exergy analysis. In engineering exergy analysis applications, according to different analysis objects and different analysis requirements, different accuracy models can be used for the established analysis models. At present, the models widely used in engineering exergy analysis can be divided into three types according to the requirements of analysis accuracy: black-box analysis model, white box analysis model, and grey box analysis model. The black-box analysis model is suitable for rough analysis, the white box analysis model is suitable for fine analysis, and the analysis accuracy of the gray-box analysis model is between the black-box analysis model and the white box analysis model. The three types of exergy flows, namely, input exergy, output exergy, and exergy within the system, are represented on a box as the system boundary, which constitutes an engineering exergy analysis model, as shown in Figure 1.

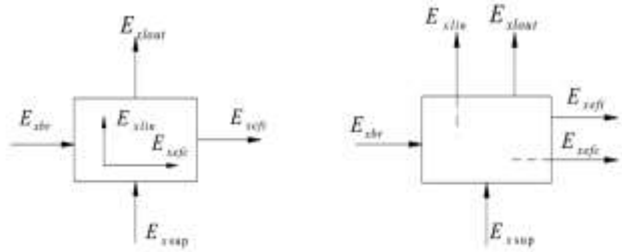

***Fig. 1**. Engineering exergy analysis and exergy balance general model*

According to the above model, we can obtain the exergy equilibrium equation of the research object:

$$E_{xsup} + E_{xbr} = \left(E_{xeft} + E_{xefc}\right) + E_{xlin} + E_{xlout} \tag{5}$$

Where $E_{xef} = E_{xef} + E_{xlin} - E_{xlout}$, the exergy balance equation for engineering：

$$E_{xsup} = E_{xef} + E_{xlin} + E_{xlout} \tag{6}$$

Where, Exef or net effective exergy.

The object of exergy analysis may be a process of energy use, an energy-consuming device, or a production system containing several sets of equipment. For different objects, there are some indicators that reflect the characteristics of different objects. The performance indicators can use to evaluate the rationality of the heater equipment energy use. The efficiency exergy ηex refers to the ratio of exergy obtained to achieve the purpose to the exergy consumed for the cost. The exergy efficiency of the heater device of the power plant regenerative system can be expressed as [23]:

$$\eta_{ex} = \frac{E_{out}^L - E_{in}^L}{E_{in}^H - E_{out}^H} \tag{7}$$

Where,

E_{in}^L exergy when cold fluid (feed water, etc.) flows into the heater,

E_{out}^L exergy when cold fluid (feed water, etc.) flows out of the heater,

E_{in}^H exergy when hot fluid (steam, water-repellent, etc. from the superior) flows into the heater,

E_{out}^H Exergy when hot fluid (such as hydrophobic) flows out of the heater.

The exergy loss rate of the equipment process is the ratio of the exergy loss of the equipment to the total exergy loss of the system, that is,

The exergy loss rate of the equipment process is the ratio of the exergy loss of the equipment to the total exergy loss of the system, that is,

$$e_{x,i} = \frac{E_{xl.i}}{E_T}$$

(8)

Where, $E_{xl.i}$Exergy of equipment, E_T total exergy of system

The exergy loss coefficient of the equipment process is the ratio of the exergy loss of the equipment to the total consumption exergy of the system, that is,

$$\lambda_i = \frac{E_{xl.i}}{E_{x.sup}}$$

(9)

Where, $E_{x.sup}$ total consumption of the system is exergy.

The exergy Unit used to produce a unit quantity of product.

$$k = \frac{E_{i,sup}}{E_P}$$

(10)

Where, $E_{i,sup}$ for consumer fire equipment, E_P for product fire equipment.

The exergy loss coefficient λ_i at each link will cause excessive fuel consumption.

$$\Delta b_i = 122.8\frac{\lambda_i}{1-\lambda} \quad [\frac{g}{kW.h}]$$

(11)

3. MODELING OF THERMAL POWER PLANT

After determining the steam extraction coefficient from the above general exergy matrix equation, combined with the exergy loss matrix equation of the thermal system [3, 24-28] and each exergy analysis and evaluation index, a comprehensive exergy analysis can be performed on the thermal system to find weak links in the system [29].

3.1 Thermal System Units

After determining the steam extraction coefficient from the above general exergy matrix equation, combined with the exergy loss matrix equation of the thermal system [3, 24-28] and each exergy analysis and evaluation index, a comprehensive exergy analysis can be performed on the thermal system to find weak links in the system [29].

3.1 Thermal System Units

As shown in Figure 2, it can divide the steam turbine installation system part of the thermal system of a power plant into eight extraction units and one condensing unit. When a detailed analysis of the energy system is needed, it is not enough to make a general evaluation of the system as a whole. In order to facilitate the detailed analysis and calculation of the exergy loss of the steam turbine thermal system, the entire steam turbine thermal system can be divided into several Units, and then analyze and calculate the exergy loss of each unit.

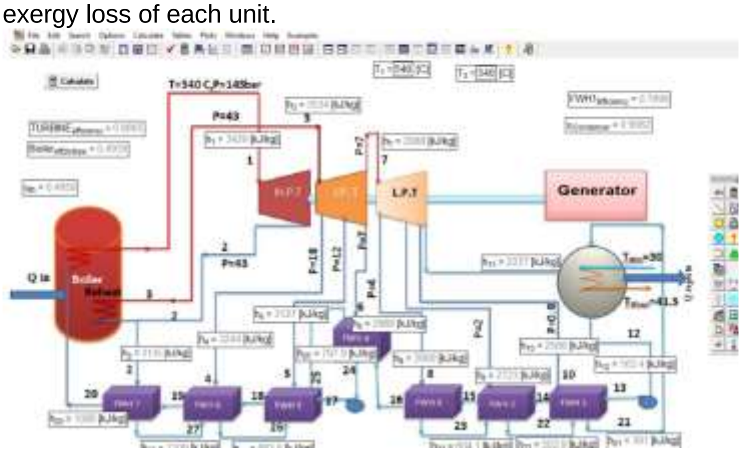

***Fig.**2. Model of a steam power plant*

The extraction unit, it is represented by the symbol UC. Similarly, the whole of the turbine through-flow part between the condenser and the steam turbine exhaust port to the lowest-level recuperative extraction port is called the condensing unit, and it is represented by the symbol UN. For a z-stage regenerative steam turbine plant system, it can be divided into (z+1) units, of which z extraction units and one condensing unit.

3.2 Exergy loss Mathematical model

The exergy loss matrix equation of this system is taking the thermal system shown in Figure 2 as,

$$\begin{bmatrix}\pi_1\\\pi_2\\\pi_3\\\pi_4\\\pi_5\\\pi_6\\\pi_7\\\pi_8\\\pi_n\end{bmatrix}=\begin{bmatrix}K_1&k_1&k_1&k_1&k_1&k_1&k_1&k_1&k_1\\&K_2&k_2&k_2&k_2&k_2&k_2&k_2&k_2\\&&K_3&k_3&k_3&k_3&k_3&k_3&k_3\\&&&K_4&k_4&k_4&k_4&k_4&k_4\\&&&&K_5&k_5&k_5&k_5&k_5\\&&&&&K_6&k_6&k_6&k_6\\&&&&&&K_7&k_7&k_7\\&&&&&&&K_8&k_8\\&&&&&&&&K_n\end{bmatrix}\begin{bmatrix}\alpha_1\\\alpha_2\\\alpha_3\\\alpha_4\\\alpha_5\\\alpha_6\\\alpha_7\\\alpha_8\\\alpha_n\end{bmatrix}+\begin{bmatrix}q_{e1}\\\gamma_{e2}&q_{e2}\\\gamma_{e3}&\gamma_{e3}&q_{e3}\\\gamma_{e4}&\gamma_{e4}&\gamma_{e4}&q_{e4}\\\tau_{e5}&\tau_{e5}&\tau_{e5}&\tau_{e5}&q_{e5}\\\tau_{e6}&\tau_{e6}&\tau_{e6}&\tau_{e6}&\gamma_{e6}&q_{e6}\\\tau_{e7}&\tau_{e7}&\tau_{e7}&\tau_{e7}&\gamma_{e7}&\gamma_{e7}&q_{e7}\\\tau_{e8}&\tau_{e8}&\tau_{e8}&\tau_{e8}&\gamma_{e8}&\gamma_{e8}&\gamma_{e8}&q_{e8}\\\tau_{en}&\tau_{en}&\tau_{en}&\tau_{en}&\tau_{en}&\tau_{en}&\tau_{en}&\tau_{en}&q_{en}\end{bmatrix}\begin{bmatrix}\alpha_1\\\alpha_2\\\alpha_3\\\alpha_4\\\alpha_5\\\alpha_6\\\alpha_7\\\alpha_8\\\alpha_n\end{bmatrix}-\begin{bmatrix}\tau_{e1}\\\tau_{e2}\\\tau_{e3}\\\tau_{e4}\\\tau_{e5}\\\tau_{e6}\\\tau_{e7}\\\tau_{e8}\\\tau_{en}\end{bmatrix} \quad (12)$$

Where, $K_i = k_i + \pi_{ci}$, $K_n = k_n + \pi_{cn} = k_n$。

Can be abbreviated as:

$$\Pi_e = [K_e][X_e] + [A_e][X_e] - [T_e] \quad (13)$$

The Eq.(13) shows that the exergy loss in each unit includes two items: one is ($[K_e][X_e]$) , which indicates that the steam turbine flow in a unit is due to steam exergy loss caused by non-isentropic expansion and pressure loss of the steam extraction pipeline. According to Eq.(12), the exergy loss matrix equation of the actual thermal system of Baiji steam Power Plant, Iraq is as follows:

$$\begin{bmatrix}\pi_1\\\pi_2\\\pi_3\\\pi_4\\\pi_5\\\pi_6\\\pi_7\\\pi_8\\\pi_n\end{bmatrix}=\begin{bmatrix}K_1&k_1&k_1&k_1&k_1&k_1&k_1&k_1&k_1\\&K_2&k_2&k_2&k_2&k_2&k_2&k_2&k_2\\&&K_3&k_3&k_3&k_3&k_3&k_3&k_3\\&&&K_4&k_4&k_4&k_4&k_4&k_4\\&&&&K_5&k_5&k_5&k_5&k_5\\&&&&&K_6&k_6&k_6&k_6\\&&&&&&K_7&k_7&k_7\\&&&&&&&K_8&k_8\\&&&&&&&&K_n\end{bmatrix}\begin{bmatrix}\alpha_1\\\alpha_2\\\alpha_3\\\alpha_4\\\alpha_5\\\alpha_6\\\alpha_7\\\alpha_8\\\alpha_n\end{bmatrix}.$$

$$\begin{bmatrix} q_{e1} \\ \gamma_{e2} & q_{e2} \\ \gamma_{e3} & \gamma_{e3} & q_{e3} \\ \gamma_{e4} & \gamma_{e4} & \gamma_{e4} & q_{e4} \\ \gamma_{e5} & \gamma_{e5} & \gamma_{e5} & \gamma_{e5} & q_{e5} \\ \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & q_{e6} \\ \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \gamma_{e7} & q_{e7} \\ \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \gamma_{e8} & \gamma_{e8} & q_{e8} \\ \tau_{en} & \tau_{en} & \tau_{en} & \tau_{en} & \tau_{en} & \tau_{en} & \tau_{en} & \tau_{en} & q_{en} \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \\ \alpha_8 \\ \alpha_n \end{bmatrix} - \begin{bmatrix} \tau_{e1} \\ \tau_{e2} \\ \tau_{e3} \\ \tau_{e4} \\ \tau_{e5} \\ \tau_{e6} \\ \tau_{e7} \\ \tau_{e8} \\ \tau_{en} \end{bmatrix} \quad (14)$$

Table 1 Extraction coefficient of each working condition

Extraction coefficient	Rated working conditions	Summer conditions	VWO conditions	THA conditions	75%THA conditions	50%THA conditions	All stop working conditions
α1	0.1103	0.1077	0.1076	0.1056	0.091	0.0782	0
α2	0.0496	0.0507	0.0506	0.0499	0.0486	0.0379	0
α3	0.0434	0.0473	0.0472	0.0468	0.043	0.0400	0
α4	0.0403	0.0382	0.0381	0.0379	0.0357	0.0343	0

Where $[K_e]$ in this term is a $(z+1)\times(z-1)$ upper triangular matrix composed of K_1 to K_n and k_1 to k_n. The elements on the diagonal of the matrix are $K_1$to K_n, and the elements on the other rows are the same. $[X_e]$ is a column matrix composed of α_1 toα_n , which represents the mass [Grab your reader's attention with a great quote from the document or use this space to emphasize a key point. To place this text box anywhere on the page, just drag it.] attenuation of steam in each unit Steam or condensate); the other is $([A_e][X_e]-[T_e])$, which indicates the exergy loss in the regenerative heater due to heat dissipation and limited temperature difference heat transfer or in the condenser, $[A_e]$ is the lower triangular matrix composed of exergy τ_{ei} for exergy γ_{ei} for hydrophobicity in the heater. $[T_e]$ is τ_{ei}Column matrix consisting of τ_{en}.The general exergy matrix equation (8) constructed is used to determine the steam extraction coefficient of the unit's thermal system. Fill in the main system structure matrix D and the auxiliary system structure matrix Df, Dτ, ΔEQ according to the actual thermal system structure. There is no auxiliary soda in and out of the system from the feedwater side, so Dτ is regarded as a zero matrix. The general exergy matrix equation of the actual thermal system of this unit is as follows.

$$\begin{bmatrix} q_{e1} & & & & & & & 0 \\ \gamma_{e2} & q_{e2} \\ \gamma_{e3} & \gamma_{e3} & q_{e3} \\ \gamma_{e4} & \gamma_{e4} & \gamma_{e4} & q_{e4} \\ \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & q_{e5}+\tau_{e5} \\ \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & q_{e6} \\ \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \gamma_{e7} & q_{e7} \\ \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \gamma_{e8} & \gamma_{e8} & q_{e8} \end{bmatrix} \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \\ D_6 \\ D_7 \\ D_8 \end{bmatrix} + \begin{bmatrix} 0 & & & & & & & 0 \\ \gamma_{e2} & q_{fe2} \\ \gamma_{e3} & \gamma_{e3} & 0 \\ \gamma_{e4} & \gamma_{e4} & \gamma_{e4} & 0 \\ \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & \gamma_{e5}+\tau_{e5} & q_{fe5}+\tau_{e5} \\ \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & \tau_{e6} & 0 \\ \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \tau_{e7} & \gamma_{e7} & 0 \\ \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \tau_{e8} & \gamma_{e8} & \gamma_{e8} & q_{fe8} \end{bmatrix} \begin{bmatrix} 0 \\ D_{f2} \\ 0 \\ 0 \\ D_{f5} \\ 0 \\ 0 \\ D_{f8} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \Delta E_{Q5} \\ 0 \\ 0 \\ \Delta E_{Q8} \end{bmatrix} = D_{fw} \begin{bmatrix} \tau_{e1} \\ \tau_{e2} \\ \tau_{e3} \\ \tau_{e4} \\ \tau_{e5} \\ \tau_{e6} \\ \tau_{e7} \\ \tau_{e8} \end{bmatrix}$$

(15)

4. RESULT AND DISCUSSION

4.1 Determination of the ground state

The ground state of the exergy analysis of the thermal system has an influence on the calculation results, and it should be determined based on the data during the thermal test of the steam turbine. The determination of the ground state is mainly based on the environmental parameters during the test, with reference to the boiler inlet fan temperature and the condenser inlet cooling water temperature. In this paper, the reference temperature and pressure for exergy analysis are t0=293.15K (20°C), p0 =0.1MPa, and the reference substance is saturated water at the reference temperature. The designed fuel type of Biji steam Power Plant, Iraq, with a low calorific value of 22440kJ/kg. When the ambient temperature is 20°C, the latent heat of water vaporization is 2453.55kJ/kg, and the moisture content is 9.61%. It can be known from Eq.(8) that the fuel exergy of fuel is 42675.79kJ/kg. The above Eq.(15) is used to calculate the steam extraction coefficient of the unit's thermal system under different operating conditions. The calculation results are shown in Table 1 below.

4.2 Analysis of exergy economic indicators

Exergy loss can be seen in the equipment or process with large losses, but in the analysis, in order to accurately compare the degree of exergy use and irreversibility in various processes or equipment under different working conditions, only the absolute amount of exergy loss is known. The exergy efficiency of the equipment reflects the real situation of the thermodynamic perfection of the system or equipment; Therefore, the exergy loss rate and exergy loss coefficient of the equipment are introduced, which can fully characterize the proportion of exergy loss of each system in the total exergy loss, and reflect the distribution of these exergy losses in each link of the system. Therefore, the "weak link" of the device can be identified, and the energy saving potential is pointed out accordingly, so that we can take corresponding measures to improve the weak link. From the literature [26-29], it can be seen that the energy saving potentials are, in order from large to small, boilers, turbines, condensers, and regenerative heater systems. However, without changing the circulation mode, the potential for further reducing the exergy loss of the boiler is not great. Therefore, for a running thermal power plant, improving and optimizing the steam turbine installation system is the focus of energy-saving workers' efforts. This paper focuses on the calculation of exergy loss, exergy efficiency and exergy loss coefficient of each subsystem in the regenerative system under varying operating conditions. The steam extraction coefficient calculated by Eq.(14), the total exergy losses of heaters, condensers and systems at all levels under different operating conditions can be obtained, as shown in Table 2.

Table 2 Exergy loss under various working conditions

Extraction coefficient	Rated working conditions	Summer conditions	VWO conditions	THA conditions	75%THA conditions	50%THA conditions	All stop working conditions
π1	7.355	1.152	1.419	2.852	16.170	18.670	25.010
π2	1.465	3.124	0.187	2.327	7.077	4.774	10.320
π3	5.390	7.763	7.801	7.244	8.110	7.985	6.655
π4	4.545	6.865	6.712	6.733	7.212	7.647	6.010

The exergy efficiency definition used to calculate the exergy efficiency of heaters and condensers at different levels under different operating conditions, as shown in Table 3. To calculated the exergy loss coefficients of heaters and condensers at different levels under different operating conditions can be obtained, as shown in Table 4 shown.

Table 3 Exergy efficiency in each working condition

xtraction oefficient	Rated working conditions	Summer conditions	VWO conditions	THA conditions	75%THA conditions	50%THA conditions	All stop working conditions
η1	0.936	0.987	0.984	0.967	0.784	0.718	-
η2	0.972	0.929	0.996	0.947	0.823	0.848	-
η3	0.905	0.866	0.864	0.874	0.838	0.814	-
η4	0.906	0.847	0.849	0.848	0.815	0.775	-

Table 4 Exergy Loss Coefficients for Various Operating Conditions

Extraction coefficient	Rated working conditions	Summer conditions	VWO conditions	THA conditions	75%THA conditions	50%THA conditions	All stop working conditions
λ1	0.064	0.0132	0.033	0.0327	0.216	0.2824	-
λ2	0.028	0.0712	0.053	0.0534	0.177	0.1524	-
λ3	0.095	0.1338	0.126	0.1261	0.162	0.1861	-
λ4	0.094	0.1529	0.152	0.1516	0.185	0.2253	-

In order to clearly see the equipment or process with large exergy loss, the line chart of the data in Table 2 is as follows: From Figure 3 shows that the exergy losses of deaerators and condensers are the largest under various operating conditions. The exergy losses of high-pressure heaters are generally greater than the exergy losses of low-pressure heaters. Figure 4, the total exergy loss of all high-discontinued operating conditions is the largest, followed by summer operating conditions.

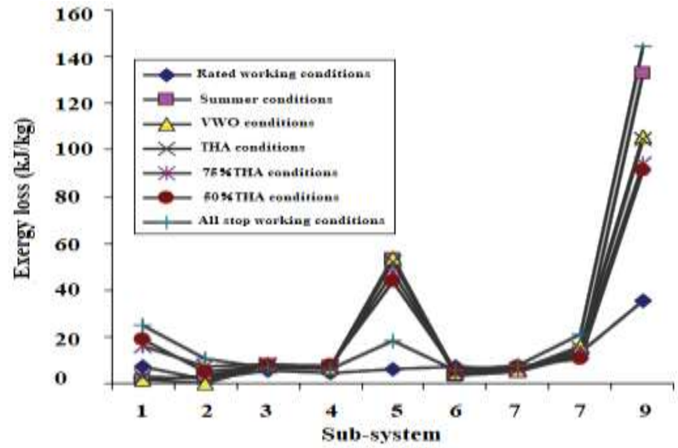

***Fig.**3. Exergy loss comparison of each sub-system under each working condition*

***Fig. 4**. Comparison of total exergy losses of thermal systems under various operating conditions*

Figure 5, shows the exergy efficiency of the deaerator and condenser is generally low under each working condition, and the exergy efficiency of the last low-pressure heater is also very low; the fire of each sub-system under THA working condition The lowest utilization efficiency, that is, the lowest energy consumption level of each equipment under this operating condition, the highest exergy efficiency of each sub-system under rated operating conditions, and the best thermodynamic perfection of each equipment when operating under this operating condition. Figure 6 shows that as the load decreases, the exergy efficiency of each sub-system gradually decreases, and the lower the load, the exergy efficiency of the first-stage high-pressure heater and the last-stage low-pressure heater will be sudden.

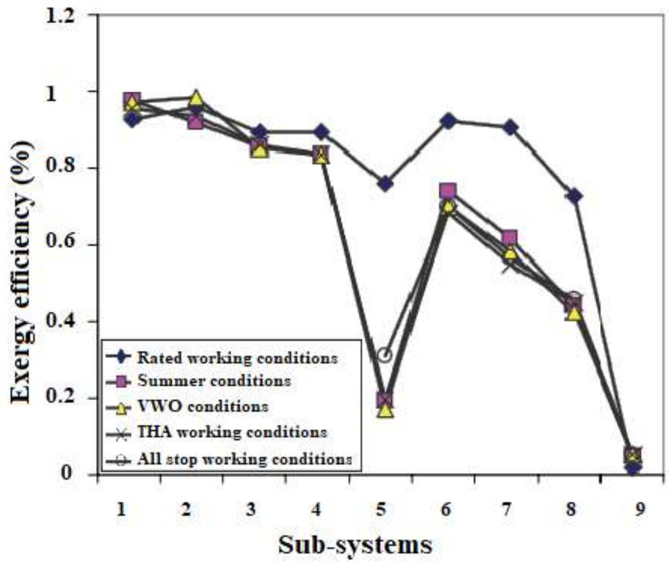

***Fig. 5**. Comparison of exergy efficiency of each sub-system under each working condition*

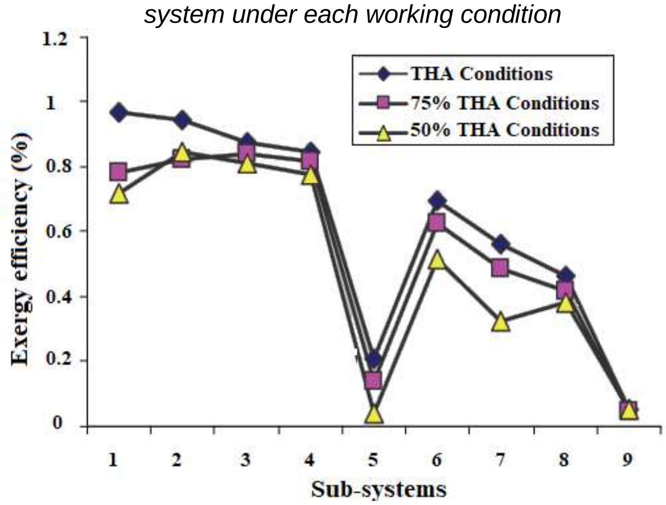

***Fig.6**. Comparison of exergy efficiency of each sub-system under variable operating conditions*

Figure 7 show that under each working condition, the condenser with the highest exergy loss is the condenser, followed by the deaerator, and the last low-pressure heater is also large. Steam generator, deaerator, low pressure heater, high pressure heater. In addition, from Figure 8 shows that as the load decreases, the exergy loss coefficient of each sub-system gradually increases, and at lower loads, the exergy loss coefficients of the first high-pressure heater and the last low-pressure heater increase significantly. These two are also weak points in the system.

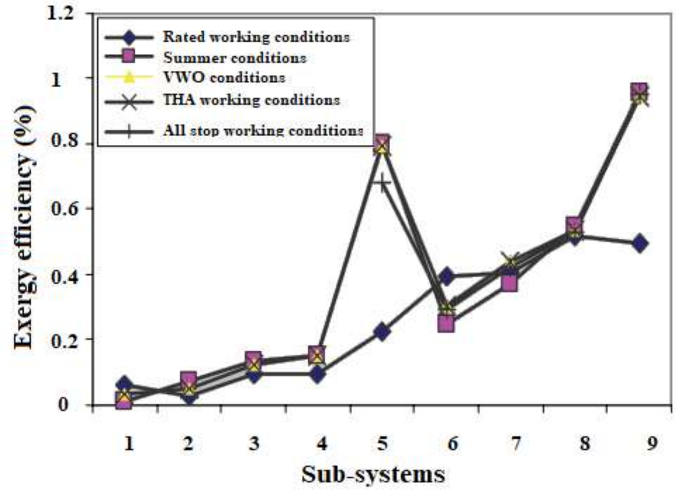

***Fig.7**. Comparison of exergy loss coefficients of each sub-system under each working condition*

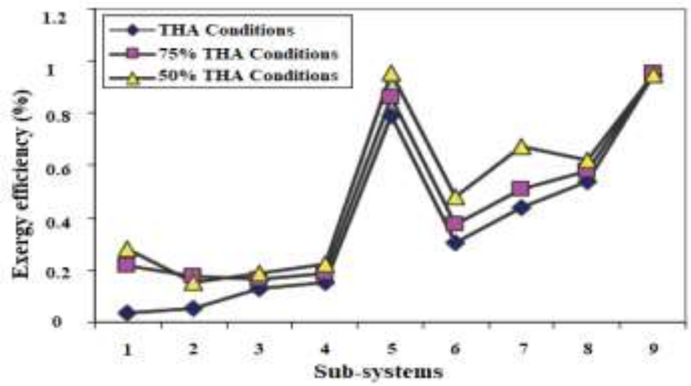

***Fig.8**. Comparison of exergy loss coefficients of various sub-systems under variable operating conditions*

5. CONCLUSION

According to the exergy analysis of the thermodynamic system of the second law of thermodynamics above, it can be concluded that the deaerator unit and the condenser unit are the weakest links in the system. In addition, the first-stage high-pressure heater extraction unit. The energy saving potential of the extraction unit of the low-pressure heater is also very large. According to the change rule of exergy analysis, it can provide a certain scientific basis for the optimization of the safe and economic operation of the steam turbine thermal system. The optimization and transformation of the two-stage sewage recovery and utilization system of Biji,Iraq Power Plant concludes that sewage drainage as the heating heat source improves the thermal economy the most and reduces the unit's standard fuel consumption rate by 0.248gkW·h.

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