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Modern Thermodynamic Analysis by the Energic-Exergic Method of Gas Turbine Power Plants 55 MW in Taza-Iraq

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ABSTRACT

Abstract Because of the increasing demand for energy in the recent period, it has become necessary to intensify the study in the field of evaluating the performance of the gas station under the first and second laws efficiency. The energy and exergy losses of gas stations are represented by the compressor, combustion chamber, and turbine. Therefore, this work aims to analyze the energy and exergy of a 55 MW Taza gas power station. The investigation demonstrated that the most significant misfortunes of the exergy happened in the combustion chamber, where was 66.5MW the most minimal misfortunes in the compressor 5MW while the misfortunes in the turbine 8.4MW. The thermal efficiency of the gas turbine power plant was 33.06%, while the exergy efficiency was 32.39%. The novelty of the current work concentrated on obtaining the Grassmann graph for each component.

1. Introduction

The expanding interest for vitality has driven specialists to look to diminish the warm misfortunes as a rule, and the influence plants misfortunes specifically in light of the fact that it is significant in gathering the world's vitality needs in the local and mechanical use. The reception of vitality examination on a quantitative premise just, as in the investigation of the principal law of thermodynamics, does not give a far-reaching impression of the examination of any power station. The kind of vitality can be dictated by the accessible or conceivable work, which is known as the exergy. The reception of the Second Law of thermodynamics as a premise in the examination of intensity stations could be more far-reaching than the main law by applying the law to ascertain the misfortunes of the exergy through every part of the (GTPP) by Bejan and Dincer [1, 2]. The way toward deciding misfortunes enables us to maintain a strategic distance from the reversibility of strategies and accordingly improve the general productivity of the plant. To decide the misfortunes of the exergy to any influence station, it is important to decide the sort of loss of physical such as grinding or synthetic, for example, burning, and therefore locate the best answer for lessening these

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misfortunes, can be seen in review papers by several authors [3-5]. A few examinations have been directed to decide the misfortunes of the vitality in (GTPP). Every one of these investigations demonstrated that misfortunes are most prominent in the ignition chamber on account of the enormous contrast in temperature and that misfortunes are a component of the temperature of passage to the turbine, was also conducted by [6-7]. The impact of encompassing temperature positively affects the proficiency of exergy by Ebadi and Bandpy [8]. The high entry temperature of the compressor has a negative effect. Therefore, air-cooling systems being used, which improves the efficiency of the first and second laws of thermodynamics by Ehyaei *et al.,* [9]. Another study was conducted to show the effect of fog system on the efficiency of the first and second law and its effects on the environment. The results proved that using this system increases energy production and improves the second law efficiency by Ehyaei *et al.,* [10]. The rise in temperature often affects performance. I used a heat pump to cool the air entering the station. The results proved that the use of the heat pump improves energy productivity as well as reduces oxygen losses by Yazdi *et al.,* [11]. A new study was conducted designing three NSGA-II, MOPSO, and MOEA-D algorithms to analyze the energy and exergy of a gas power plant. The results showed that the greatest losses to the exergy are in the combustion chamber, noting that the best results were achieved in the NSGA-II algorithm by Shamoushaki *et al.,* [12]. A study was conducted to analyze the performance of a gas station and the effect of operational and design variables on CO_2 emissions. It turns out that higher entry temperature and greater compression ratio reduce CO_2 emissions by Shamoushaki and Ehyaei [13]. We conducted previous studies to analyze energy and exergy in the traditional way by Ahmed *et al.,* [14] and using Sankey and Grassmann diagrams, respectively. This study is a continuation of previous work as shown in by Khan [15]. The methodology of exergy analysis can be found in one of the states of art studies in the field of Absorption cycles optimization, the study was seek to show the relation between the (EDR) and the volume flow rate of (CNG & LPG) within the double effect of parallel and series flow direct-fired absorption systems with lithium bromide–water. The results showed that (COP) of parallel flow cycle was (3-6%) higher than series one, and the minimum (EDR) of parallel flow cycle is around (4%) less than while energy consumption was (2-3%) low than the series one by Azhar and Siddiqui [16]. Finally, another study conducted on finding and comparing between the optimum parameters in different components of the lithium bromide-water based single to triple effect direct and indirect fired vapour absorption systems in order to get higher exergy effect with lower exergy destruct. It seeks revealing that the double effect cycle shows higher exergy effectiveness when the temperature variance between the energy source and the generator is (6-37°C); however triple effect cycle performs well at ($\cong 37°C$) by Azhar and Siddiqui [17].

Gas stations are common in Iraq recently, because the ambient temperature rises in the summer to $50\ °C$ and it drops in the winter to $-10\ °C$ which has a clear impact on the exergy losses. The previous literatures did not study of energy and exergy analysis in such conditions. So, this work came to study the energy and exergy analysis using the analytical method and the Grassmann chart, respectively.

2. Methodology

Series of analysis of initial data, necessary calculation, and graphical illustration of the results are shown in the methodology scheme Figure 1. The following calculations compliance with the technological scheme indicates a model to calculate every stage efficiency of the GTPP. For precision of the results, flow and Grassmann diagrams are the choice for both energy and exergy analysis.

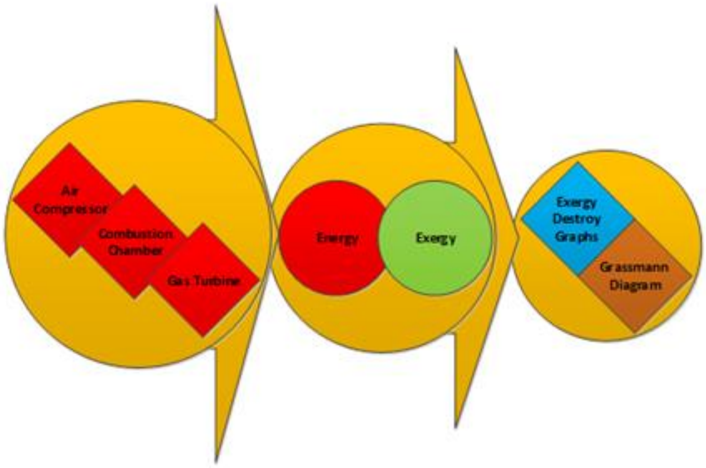

Fig. 1. Algorithm of methodology

2.1 System Description and Initial Data

Data such as pressure, the power generated, the power produced, the temperature everything being equal, and mass stream rate (gas, air, and fuel) were taken from the information sheet books for (GTPP) [18]. The surrounding temperature is 280 K and the weight of 1.013 Bar. The GTPP of 55 MW burden utilized within this particular examination is an open cycle single-shaft framework and is situated at TAZA, Iraq. The sketch diagram of the gas turbine unit appears in Figure 2. This unit comprises of Gas Turbine, Combustion Chamber, and an Air-Compressor. Working liquid parameters for the figures of exergy and energy, for example, temperature, weight, enthalpy, and mass stream rate, are situated at each point in Figure 2.

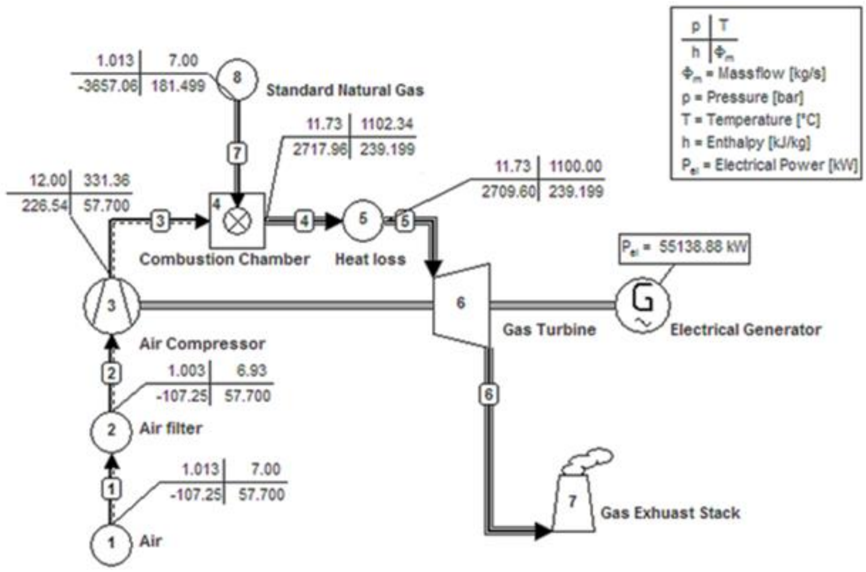

Fig. 2. Sketch diagram of a single shaft (GTPP)

2.2 Energy Analysis

Thermal evaluation of gas turbine and compressor components comprises the tally of work and heat in accordance to the basic essentials of the thermodynamic energy equation, as reveal below.
Compressor work:

$$W_C = \dot{m}Cp_a(T_3 - T_2). \tag{1}$$

Heat added:

$$q_{ad} = \dot{m}Cp_g(T_4 - T_3). \tag{2}$$

Turbine work:

$$W_T = \dot{m}Cp_a(T_6 - T_5). \tag{3}$$

Heat rejected:

$$q_{ex} = \dot{m}Cp_g(T_7 - T_6). \tag{4}$$

Net work:

$$W\_net = W\_T - W\_C. \tag{5}$$

Thermal efficiency:

$$\eta_{th} = \frac{W_{net}}{q_{ad}}. \tag{6}$$

2.3 Exergy Analysis

The modern thermodynamic analysis technology is Exergy analysis that employees and proceeds both the precept of mass and energy conservation with the entropy generation equation in order to carry out the analysis [2]. The sum of physical exergy, chemical exergy, kinetic exergy, and potential one for any system is the overall exergy as given in Eq. (7) [1].

Exergy analysis concerns with evaluated the conditional property "Exergy" from combining the mass and energy conservation fundamentals with the second law of thermodynamics.

$$\dot{E}_x = \dot{E}_x^{PH} + \dot{E}_x^{CH} + \dot{E}_x^{KN} + \dot{E}_x^{PT}. \tag{7}$$

Assuming potential and kinetic exergy approximated zero. Know we can get physical exergy from the following equation:

$$\dot{E}_x^{PH} = \dot{m}\left[c_p(T_i - T_o) - T_o(s_i - s_o)\right], \tag{8}$$

$$s_i - s_o = \bar{c_p}\, ln\left(\frac{T_i}{T_o}\right) - Rln\left(\frac{P_i}{P_o}\right), \tag{9}$$

$$\bar{c_p} = a + bT + cT^2 + dT^3. \tag{10}$$

The chemical exergy of hydrocarbon fuel C_aH_b is shown below [19]:

$$\frac{e_f{}^{-CH}}{\mathrm{LHV}} \cong 1.033 + 0.019 - \frac{b}{a} - \frac{0.098}{a}. \tag{11}$$

Exergy destruction is given by:

$$\dot{E}_D = \dot{E}_{x_{in}} - \dot{E}_{x_{out}}. \quad (12)$$

While the second law efficiency for each part of the station can be expressed by:

$$\eta_{\text{II}} = \frac{\dot{E}_{x_{out}}}{\dot{E}_{x_{in}}}. \quad (13)$$

Finally, the total second law efficiency can be expressed by:

$$\eta_{\text{II,total}} = \frac{\dot{W}_{GT,net}}{\dot{E}_{xcc}}. \quad (14)$$

3. Results and discussion

The outcomes are demonstrating and specified in Table 1 and Table 2 and presented in Figure 3 by Grassmann diagram.

Table 1
Exergy destruction rate & Exergy efficiency of (GTPP) components

References	Exergy destruction rate (%)			Exergy efficiency (%)		
	Air compressor	Combustion chamber	Gas turbine	Air compressor	Combustion Chamber	Gas turbine
Igbong *et al.,* [20]	3.53	86.38	10.12	93.07	54.05	65.27
Egware *et al.,* [21]	3.63	93.34	3.02	92.05	45.46	96.39
Al-Taha *et al.,* [22]	3.69	93.10	3.21	91.95	45.85	9617
Abam *et al.,* [23]	12.04	61.25	26.74	70.2	30.67	60.35
Siahaya *et al.,* [24]	17.81	92.00	7.20	91.00	87.00	98.50
Al-Doori [25]	12.33	71.03	16.65	82.56	75.71	92.48
Current research	5.4	83.4	10.8	94	77	97

Table 2
First and second law efficiency of (GTPP)

NO	References	First law efficiency (%)	Second law efficiency (%)
1	Igbong *et al.,* [20]	31.05	30.81
2	Al-Doori [25]	33.77	32.25
3	Current research	33.06	32.39

The exergy input and exergy distraction in the combustion chamber, turbine, compressor, and exhaust are appearing in the "Grassmann diagram" GTPP in Figure 3.

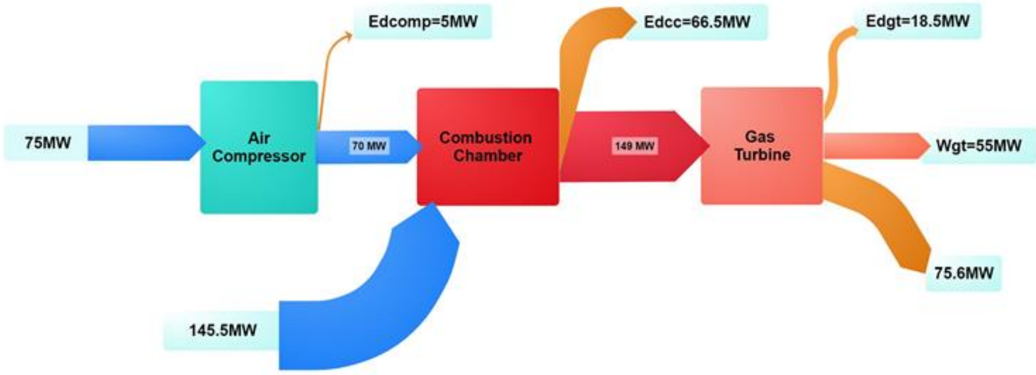

Fig. 3. Grassmann diagram of Taza GTPP

Figure 3 and Table 1 demonstrate the Exergy devastation rate and the Exergy proficiency for all GTPP segments. The greatest exergy annihilation happens in the ignition chamber, and it is equivalent to 66.5 MW with exergy devastation rate and second law productivity of (83.4%) and (77%) individually. It was trailed by the gas turbine with 8.4 MW with exergy pulverization rate and second law effectiveness of (10.8%) and (97%) separately. The base exergy devastation happens in the blower, and it is equivalent to 5 MW with exergy pulverization rate and second law productivity of (5.4%) and (94%) individually. It tends to be chosen that the most extreme exergy demolition rate and the base exergetic effectiveness are situated in the burning chamber. The base exergy pulverization rate is situated in the blower, and the greatest energetic effectiveness is situated in the gas turbine. Table 2 demonstrates the first law proficiency and second law productivity of the GTPP, the principal law effectiveness is 33.06%, and the second law productivity is 32.39%. Ordinarily, this affirms with the aftereffects of references that organize in Table 2. The most extreme exergy demolition rate and the base exergetic proficiency happen in the burning chamber brought about by deficient ignition and warmth misfortune to the surrounding [26]. The exergy proficiency of the (GTPP) is lower than the vitality productivity given the irreversibility in the framework.

4. Conclusions

In this study, the exhibition of a GTPP was assessed by utilizing vitality and exergy examination. The outcomes are spoken to with the stream and Grassmann graph. Through the outcomes, it was discovered that the most extreme and the base exergy losses were up to 83.4% or 66.5 MW, which take place in the ignition chamber, and 5.4% or 5 MW, which take place noticeable all around the blower. The Exergy productivity of the Air blower, Combustion Chamber, and Gas turbine is 97%,77%, and 94% individually. The exergy productivity and warm effectiveness of the GTPP are 32.25% and 33.77%, individually. It very well may be chosen that exergy losses happened because of the irreversibility due to temperature contrasts between the burning chamber and the surrounding temperature.

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