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The effect study of air temperature on the thermal performance of gas-turbine unit at Zawia power plant

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دراسة تأثير درجة حرارة الجو على الأداء الحراري لوحدة التوربينات الغازية بمحطة توليد الكهرباء بالزاوية

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Abstract:
In this paper, the thermal performance of a gas turbine unit at Zawia combined cycle power plant was evaluated for the months of January and June, to determine the extent to which it is affected by the ambient air temperature. The 25% mist water injection technology was used in this plant to verify its effectiveness in enhancing the thermal performance of June by cooling the air entering the compressor. The thermal performance of the plant for the month of June was also compared before and after using the fogging water injection technique.
Initially, some thermodynamic variables were calculated, including: thermal efficiency, total electrical efficiency, and exhaust gas flow rate, based on the average ambient air temperatures for the months of January and June, 16°C and 45°C, respectively. The results indicate that the thermal efficiency and total electrical efficiency of the unit increase with decreasing air temperature; In January, they reached 39.8% and 36.2%, respectively, while in June they reached 39.15% and 28.76%, respectively. The results showed that using Fogging technology in the summer (June) enhances the thermal performance -power generation and the efficiency- of the gas turbines unit. It is clear from the data measured for June that the use of the fogging cooling system leads to an increase in the overall electrical efficiency of the unit by 5.24%, a decrease in the specific fuel consumption (S.F.C.) by 0.048kg/kw.hr, and the net-work (W_{net}) of kJ/kg is 6.3. Also, the decrease in the compressor inlet temperature from 318.15K to 301.6K leads to a decrease in the outlet temperature from 716K to 687K, which is a decrease of 4.1%.

Keywords: Gas turbine, Ambient air temperature, Thermal performance, Electrical efficiency, Fogging cooling system.

الملخص
تم في هذه الورقة، تقييم الأداء الحراري لوحدة التوربينات الغازية بمحطة توليد الكهرباء الزاوية للدورة المزدوجة لشهري يناير ويونيو ومعرفة مدى تأثرها بدرجة حرارة الجو المحيط. تمَّ استخدام تقنية حقن الماء الضبابي 25% في هذه المحطة للتحقق من مدى فاعليتها في تعزيز الأداء الحراري لشهر يونيو من خلال تبريد الهواء الذي يدخل للضاغط. كما تمَّ مقارنة الأداء الحراري للمحطة لشهر يونيو قبل وبعد استخدام تقنية حقن الماء الضبابي (Fogging).
في البداية، تمَّ حساب بعض المتغيرات الثيرموديناميكية منها الكفاءة الحرارية، الكفاءة الكهربائية الكلية، ومعدل تدفق غازات العادم، بالاستناد لمتوسط درجات حرارة الهواء المحيط لشهري يناير ويونيو 16°C و 45°C على التوالي. تُشير النتائج إلى

أن الكفاءة الحرارية والكفاءة الكهربائية الكلية للوحدة تزداد بتقلص درجة حرارة الهواء، ففي شهر يناير بلغتا 39.8% و36.2% على التوالي، بينما في شهر يونيو بلغتا 39.15%، 28.76% على التوالي. أظهرت النتائج أن استخدام تقنية Fogging في فصل الصيف (شهر يونيو) يعزز الأداء الحراري -توليد الطاقة والكفاءة- لوحدة التوربينات الغازية. يتضح من البيانات المقاسة لشهر يونيو أن استخدام نظام التبريد Fogging يؤدي إلى ارتفاع الكفاءة الكهربائية الكلية للوحدة بنسبة 5.24%، انخفاض معدل الاستهلاك النوعي للوقود (S.F.C) بمقدار 0.048kg/kw. hr، والشغل الصافي (W_{net}) بمقدار 6.3kJ/kg. كما أن انخفاض درجة حرارة مدخل الضاغط من 318.15K إلى 301.6K يؤدي إلى انخفاض درجة حرارة المخرج من 716K إلى 687K، وكان الانخفاض بنسبة 4.1%.

الكلمات المفتاحية: التوربينة الغازية، درجة حرارة الهواء المحيط، الأداء الحراري، الكفاءة الكهربائية، تقنية Fogging.

1. Introduction

With the increase in demand for electrical energy and the depletion of traditional sources of energy, many researchers are directed to search for methods that support and enhance the performance of electricity plants to provide the required energy. Through studying different types of power plants, the prominent role-played gas turbines were reached, including the study of Nag, which summed up that gas turbines are considered the ideal choice among all power systems, due to low cost, speed of installation, ease maintenance, rapid response to electricity changes in the electric network, also the potential to use multiple types of fuel [1], where the gas turbines convert the heat (energy) obtained from fuel to generate mechanical power. So, the gas turbine power plants are widely used to produce power in the world.

On the other hand, as a result of the thermal performance of gas turbines being affected by the surrounding environmental conditions (temperature and humidity). Using computer simulation, Kakaras *et al.* have shown that performance decreases with the increase of ambient temperature in gas turbine which are used in cogeneration and combined cycle [2]. Saravanamuttoo *et al.* concluded that a gas turbine's temperature effect curve depends on parameters of its cycle, efficiencies of components, and mass flow rate of air inlet [3]. Wafaa proved that the energy output and efficiency of the gas turbine power plant is affected by the high ambient temperature [4]. Therefore, the inlet air cooling technology was used in the gas turbine due to cost-effective among all the systems, as it increasing the power output, and the thermal efficiency of the industrial gas turbine [5].

Over the years, several techniques have been developed to cool the inlet air in a gas- turbine, including water spraying to the inlet air (fogging), proposed by Wilcox and Trout in 1951[6]. Fogging method for inlet air cooling, due to the fast and simple installation plus lower capital cost, is popular and more acceptable compared to other methods [7]. Fogging cooling method is used to reduce the work of compression per unit of compressor pressure ratio [8] and increase gas turbine power output [6]. When the air entering the gas turbine is cold, the output power is improved by 11%, according to study of Lamfon *et al.* about the performance of a gas turbine plant of 23.7 MW, which worked at ambient conditions of temperature 30 to 45ºC [9]. Dawoud *et al.* have been using cooling technology at two gas turbine plants in Oman, and the results showed that reduction of the air temperature at the gas turbine inlet, leads to 11.4% more output electric power [10]. In addition, Bracco *et al.* reported an increase of gas turbine power output of up to 14% [11], while Sanaye *et al.* [12] produced a power gain of up to 7.73%, as well as Ehyae *et al.* [13] has reported the power enhancement of gas turbine using fogging by 7%. However, Shepherd *et al.* [14] successfully achieved of up to 18%. Moreover, Ammar *et al.* studied the impact of the fogging system on the gas turbine's performance of combined cycle power plant located at BeniSuef, Egypt. In summer, the results showed that the power increased 0.78% for each 1ºC decreases in air temperature, while it was 0.42% in winter [15].

This research aims to study the effect of air temperature -as one of the important operations variational- on the gas turbine's thermal performance (thermal efficiency, compressor work, specific fuel consumption) of combined cycle power plant located at Zawia, Libya, for two months (January and June). In addition, it studies the effect of fogging technology on its performance, in order to enhance the overall electrical efficiency and power generation.

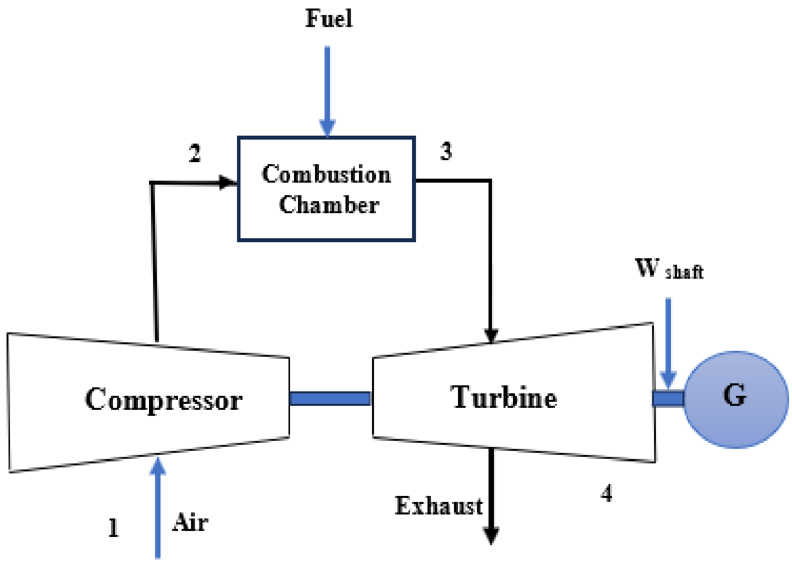
2. Materials and methods

2-1. Zawia Power Plant Description

This study includes the effect of operational conditions on the performance of the GT13E2 gas turbine unit in the power plant located at Zawia, western Libya. The plant was constructed in two phases, the first (in 2000) by the Swiss Company ABB with four gas turbine units, whose production capacity and design efficiency reach 600MW and 35%, respectively. The second (in 2005) was through the addition of two other gas units by the Swiss Company Alstom. The production capacity of the two generating units reached 330MW when operating with natural gas fuel. Currently, all units operate with natural gas fuels. Gas generation units have been developed to operate with the MXL system.

2-2. Gas turbine components and thermal analysis

Most gas turbines have four basic parts: a compressor, a combustion chamber, an open-system gas turbine for cooling the blades, and a generator. Figure (1a) is an illustrative diagram of a simple gas turbine. The basic principle of these turbines is the Open Brayton Cycle, which operates in four procedures: two pressure-constant and two entropy-constant, shown in Figure (1b) [16]. The air at room temperature enters the compressor through the air inlet at point conditions (1), to raise its pressure and temperature to exit at point conditions (2), then it moves to the combustion chamber - it is mixed with the fuel- which burns the fuel at a constant pressure to exit at point conditions (3), and the air temperature turns to a high temperature (T3). After that, the resulting gases move to the turbine to expand isentropically, losing energy, to the turbine axis to exit with point conditions (4) of temperature and pressure[17].



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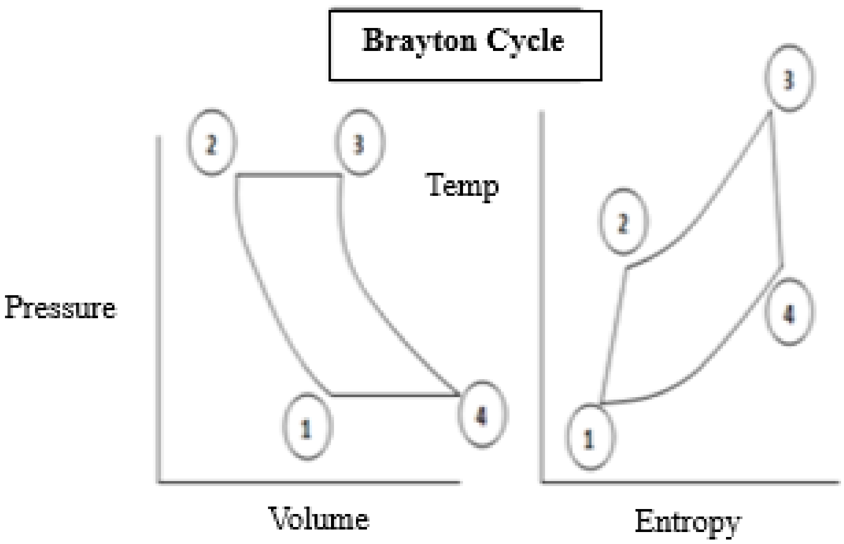

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Fig. 1. Schematic diagram of: a) Simple gas turbine. b) Brayton Cycle [16].

2-3. Power plant field data

The experimental field data for gas turbine unit (GT13E2) for the January and June months, and including the inlet and outlet temperatures of all components of the cycle, the pressure at the compressor inlet, were collected and are described in Table (1). As well as the average daily operating variables of the unit were analyzed and mean values calculated.

Table 1. Average operating variables of the Zawia gas turbine power plant in January and June months.

Thermodynamic variables	Symbol	Data	
		January	June
Air entry temperature to compressor (K)	T_1	289.15	318.15
Pressure at the compressor inlet (bar)	P_1	1.013	1.013
Compressor Pressure ratio	B_c	15.4	15.4
Temperature of gases entering the turbine (K)	T_3	1400	1400
Turbine expansion ratio	B_T	15.2	15.2
Coefficient of expansion in gases	K_{gas}	1.333	1.333
Compressibility coefficient of atmospheric air	K_{air}	1.4	1.4
Exhaust temperature (K)	T_4	847.15	847.15
fuel lower heating value (kJ/kg)	L. H. V	42553	42553
Compressor efficiency	η_c	0.85	0.85
Turbine efficiency	η_T	0.86	0.86
Combustion chamber efficiency	η_{cc}	0.95	0.93
Mechanical efficiency	η_{mech}	0.95	0.95
Generator efficiency	η_g	0.85	0.85
Unit operating capacity (MW)	P_e	166.3	133

2-4. Theoretical equations of some thermodynamic variables related to the performance of a gas turbine unit

The most important thermodynamic variables that contribute to determining the thermal performance of a gas turbine, and will be calculated in this study are:

I. The net work of a gas turbine

The net-work ($\boldsymbol{W_{net}}$) obtained from a gas turbine is given by equation (1) in kJ/kg units [18]

$$W_{net} = W_T - W_c \qquad \dots (1)$$

Where $\boldsymbol{W_T}$ is the work produced (kJ/kg), can be written depending on the expansion coefficient in gases ($\mathbf{K_{gas}}$), turbine inlet temperature ($\mathbf{T_3}$), the pressure ratio in the compressor ($\mathbf{B_c}$), the compressibility coefficient of atmospheric air ($\mathbf{K_{air}}$) and gas turbine efficiency ($\boldsymbol{\eta_T}$)

$$W_T = C_{pgas} * T_3 * \left[\frac{\left(B_c^{\left(K_{air} - \frac{1}{K_{air}}\right)} - 1 \right)}{B_c^{\left(K_{gas} - \frac{1}{K_{gas}}\right)}} \right] * \eta_T \qquad \dots (2)$$

Where $\boldsymbol{C_{Pgas}}$ (kJ/(kg * K)) is gas specific heat at constant pressure equation, we obtain

$$C_{p_{gas}} = \left[\frac{(5.23 + 9.21\alpha)}{\alpha} \right] * 10^{-5} * (T_3 + 450) + 0.913) \dots (3)$$

Where $\boldsymbol{\alpha}$ represents the air surplus coefficient (excess air) and is equal to

$$\alpha = \frac{(2600 - 0.06 * T_3)}{(T_3 - 0.92 * T_2)} \qquad \dots (4)$$

And

$$W_c = C_{P_{air}} * T_1 * \left[\frac{B_c^{\left(K_{air} - \frac{1}{K_{air}}\right)} - 1}{\eta_c} \right] \qquad \dots (5)$$

is the work of the compressor, $\mathbf{T_1}$ (K) is the temperature of air entering the compressor, which depends on the temperature of the environment surrounding the gas turbine unit, $\boldsymbol{\eta_c}$ is compressor efficiency, and $\mathbf{C_{pair}}$ (kJ/(kg*K)) is the Air specific heat at constant pressure, here determined from relation

$$C_{P_{air}} = 5.02 * 10^{-5} (T_2 - 70) + 0.988 \qquad \dots (6)$$

Here $\mathbf{T_2}$ (K) is the final temperature of the compressor, and is equal to

$$T_2 = T_1 * \left[1 + \left(\frac{B_c^{K_{air} - \frac{1}{K_{air}} - 1}}{\eta_c} \right) \right] \qquad \dots (7)$$

II. Total thermal efficiency

The thermal efficiency of a gas turbine (η_{th}) is defined by the relationship [17]

$$\eta_{th} = \left[\frac{W_{net}}{Q_{cc}}\right] \quad ... \ (8)$$

Where Q_{cc} (kJ/kg) is the heat added in the combustion chamber, and can be written depending on a combustion chamber efficiency (η_{cc})

$$Q_{cc} = C_{p_{gas}} * \frac{T3 - T2}{\eta_{cc}} \quad .... \ (9)$$

III. Specific fuel consumption

The specific fuel consumption rate (**S.F.C**) is calculated as [15, 19]:

$$S.F.C = \frac{3600 * m_{fuel}}{P_e} \quad .... \ (10)$$

Where P_e, m_{fuel} are the operating capacity of the unite and the fuel consumption rate, respectively, and m_{fuel} (kg/s) is defined as

$$m_{fuel} = \frac{P_e}{W_e * \eta_{mech} * \eta_g} * \frac{Q_{cc}}{H.V} \quad ... \ (11)$$

Where W_e (kJ/kg), η_{mech}, η_g are work available at the rotor, mechanical efficiency, and generator efficiency, respectively, and **H.V** (kJ/kg) is fuel heating value of gaseous. Equation (11) can be rewritten as

$$m_{fuel} = m_{air} * m_{\frac{fuel}{air}} \quad .... \ (12)$$

Where m_{air}(kg/sec) and $m_{fuel/air}$ (kg/kw) are the air consumption rate and the rate of fuel consumption per 1 kg of air, respectively, and defined as

$$m_{air} = \frac{P_e}{W_e * \eta_{mech} * \eta_g} \quad ... \ (13)$$

$$m_{fuel/air} = \frac{Q_{cc}}{H.V} \quad ... \ (14)$$

Where W_e (kJ/kg) obtained from the gas turbine is given by

$$W_e = W_{net} * \eta_{mech} \quad ... \ (15)$$

IV. Exhaust gas flow rate

The exhaust gas flow rate (m_{gas}) is determined by equation [19]

$$m_{gas} = m_{air} + m_{fuel} \quad ... \ (16)$$

V. Overall electrical efficiency

The overall electrical efficiency of the turbine ($\eta_{overall}$) is [15,19]

$$\eta_{overall} = \frac{P_e}{m_{fuel} * H.V} \quad ... \ (17)$$

2-5. Mist water injection system to improve gas turbine production (GT13E2)

In order to improve the efficiency of the gas turbines at the combined power plant at Zawia city, the fogging system was used. Thus, helps in increasing the efficiency of the gas turbines, especially in the ambient weather conditions (hot and humid), as well as increasing the mass flow rate of the turbines depending on the amount of water required. Figure (2) shows the diagram of the fogging input process [15].

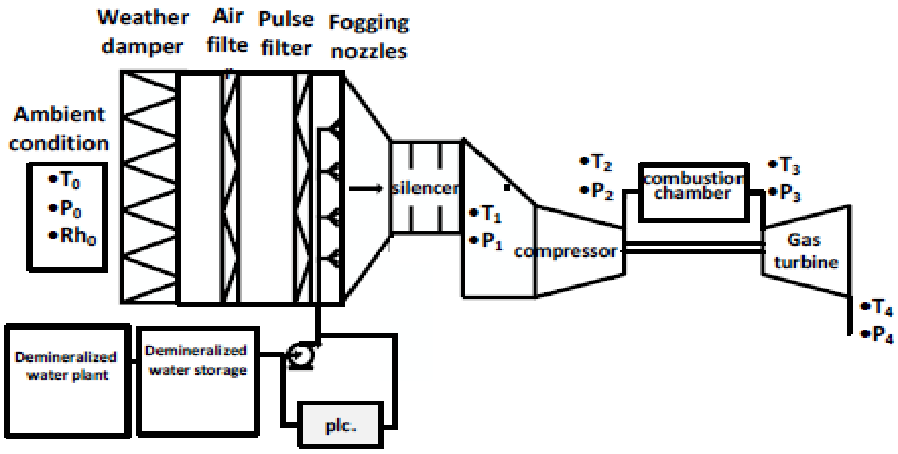

Fig. 2. Shows the diagram of the fogging input process [15].

To determine the extent of its effectiveness, calculations were conducted using the 25% mist water technique for a simple cycle of the GT13E2 gas turbine used in the plant, based on the previously mentioned equations and the operational technical specifications in June (thermodynamic variables) mentioned in Table 2. The expected maximum values of power generation $\mathbf{P_e}$ for gas turbines under the influence of ambient temperature on the turbines are listed in Table 3.

Table 2. Operational readings of a gas turbine unit in June month with the use 25% fog water technology .

Thermodynamic variables	Symbol	Date in June
Air entry temperature to compressor (K)	T_1	301.15
Pressure at the compressor inlet (bar)	P_1	1.013
Compressor Pressure ratio	B_c	15.4
Temperature of gases entering the turbine (K)	T_3	1400
Turbine expansion ratio	B_T	15.2
Coefficient of expansion in gases	K_{gas}	1.333
Compressibility coefficient of atmospheric air	K_{air}	1.4
Exhaust temperature (K)	T_4	847.15K
fuel lower heating value (kJ/kg)	L. H. V	42553
Compressor efficiency	η_c	0.95
Turbine efficiency	η_T	0.86
Combustion chamber efficiency	η_{cc}	0.93
Mechanical efficiency	η_{mech}	0.95
Generator efficiency	η_g	0.85
Unit operating capacity (MW)	P_e	141.25

Table 3. The expected maximum power generation P_e for gas turbine GT13E2 and the effect of ambient temperature [19] .

Operating mode	Produced energy	Ambient temperature outside		
		0 °C	**15 °C**	**50 °C**
Ignite the gas (Base load)	Energy produced by MW	177.6	167.7	128.7
	The Energy produced in the generating plant in MVA with cosj = 0.80	222.0	209.6	160.9

3. Results and discussion

To study the extent of the effect of atmospheric air temperatures on the gas turbine's efficiency of combined cycle power plant located at Zawia, Libya, some thermodynamic variables were calculated according to the average operational data recorded in Table (1) for the plant the two months of January and June, and also based on the above-mentioned equations (1-17) given according to reference [15, 17-19].

The calculated results for the most important thermodynamic variables (net-work, thermal efficiency, exhaust gas flow rate, specific fuel consumption rate, and total electrical efficiency) for the gas turbine unit and the average air temperatures for the January and June months showed 16°C and 45°C, respectively. thermal efficiency, exhaust gas flow rate, and total electrical efficiency of the unit increased as the ambient temperature decreased. At 16ºC, the thermal efficiency and total electrical efficiency of the unit reached 39.8% and 36.2%, respectively, as shown in Table (4). In comparison, at high ambient temperatures (Summer), the thermal efficiency and electrical efficiency of the unit, as well as the exhaust gas flow rate decrease. In June, when the average ambient temperature was 45ºC, they were 39.15%, 28.76% and 495.63 kg/sec, respectively.

Table 4. Thermodynamic variables of a gas turbine unit for the January and June months [19].

Thermodynamic variables	Symbol	Unit	Value	
			January	June
Air temperature at compressor outlet	T_2	K	650.81	716
Atmospheric air heat capacity	$C_{P\ air}$	kJ/kg. K	1.017	1.0
Work done on compressor	W_c	kJ/kg	367.8	405.95
Specific heat of gases	C_{Pgas}	kJ/kg. K	1.1142	1.1118
Excess air	α		3.288	395.3
Useful work done by turbine	W_T	kJ/kg	725.71	725.96
Net work	$\mathbf{W_{net}}$	**kJ/kg**	**357.9**	**320**
Heat added in combustion chamber	Q_{cc}	kJ/kg	897.58	817.5
Thermal efficiency of the unit	$\boldsymbol{\eta_{th}}$	**%**	**39.8**	**39.15**
Work available at the rotor	W_e	kJ/kg	340	304
Mass flow rate of air	m_{air}	Kg_{air}/sec	541.95	571.89
Rate of fuel consumption /1 kg-air	$m_{fuel/air}$	kg_{fuel}/Kg_{air}	0.021	0.019
Fuel consumption rate	m_{fuel}	kg_{fuel}/sec	11.38	10.866
Exhaust gas flow rate	$\boldsymbol{m_{gas}}$	$\mathbf{kg/sec}$	**553.33**	**495.63**
Specific fuel consumption rate	**S.F.C**	**kg/kw. Hr**	**0.2463**	**0.294**
Overall efficiency	$\boldsymbol{\eta_{overall}}$	**%**	**36.2**	**28.76**

Therefore, to improve the thermal performance of the gas turbine unit in the summer, the atmospheric air entering the compressor must cooled, and one of the methods used to reduce the atmospheric air temperature is to use a 25% mist water injection system to ensure the best efficiency of the unit. Operating the gas turbine using mist water injection technology resulted in a 25% reduction in the compressor inlet air temperature, thus resulting in a decrease in the outlet temperature of 4.1%. It was also noticed that there was an increase in the overall electrical efficiency of the gas unit from 28.76% to 34% by 5.24%, and also in the flow rate of exhaust gases from 495.63kg/sec to 519.667 kg/sec by 24.037 kg/sec. On the other hand, using a fogging cooling system resulted in a specific fuel consumption (S.F.C) of 0.048kg/kw hr. and the net wort (W_{net}) is 6.3 kJ/kg, as shown in Table 5.

Table 5. Thermodynamic variables of gas turbine unit using 25% fog water[19].

Thermodynamic variables	Symbol	Unit	Value
Air temperature at compressor outlet	T_2	K	687
Atmospheric air heat capacity	$C_{P\ air}$	kJ/kg. K	1.019
Work done on compressor	W_c	kJ/kg	373.4
Specific heat of gases	C_{Pgas}	kJ/kg. K	1.052
Excess air	α		3.276
Useful work done by turbine	W_T	kJ/kg	687
Net work	$\mathbf{W_{net}}$	**kJ/kg**	**313.7**
Heat added in combustion chamber	Q_{cc}	kJ/kg	806.54
Thermal efficiency of the unit	$\boldsymbol{\eta_{th}}$	**%**	**38.9**
Work available at the rotor	W_e	kJ/kg	298
Mass flow rate of air	m_{air}	Kg_{air}/sec	467.6
Rate of fuel consumption /1 kg-air.	$m_{fuel/air}$	kg_{fuel}/Kg_{air}	0.02
Fuel consumption rate	m_{fuel}	kg_{fuel}/sec	9.667
Exhaust gas flow rate	$\boldsymbol{m_{gas}}$	$\mathbf{kg/sec}$	**519.667**
Specific fuel consumption rate	**S.F.C**	**kg/kw. Hr**	**0.246**
Overall efficiency	$\boldsymbol{\eta_{overall}}$	**%**	**34**

Figure (3) shows the average ambient air temperature to a gas-turbine, which enters the compressor (**T_1** by ^{O}C) for the January and June months before using the fogging technology, as well as after using it in June month.

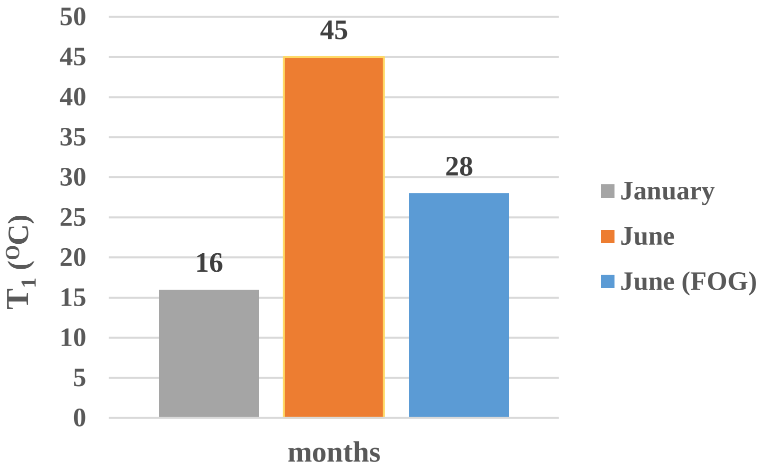

Fig. 3. Chart of average air temperature.

Figure (4) illustrates comparison the effect of the inlet air temperature on the thermodynamic variables of a gas turbine (net-work, thermal efficiency, exhaust gas flow rate, specific fuel consumption rate, and total electrical efficiency) for two months (January and June).

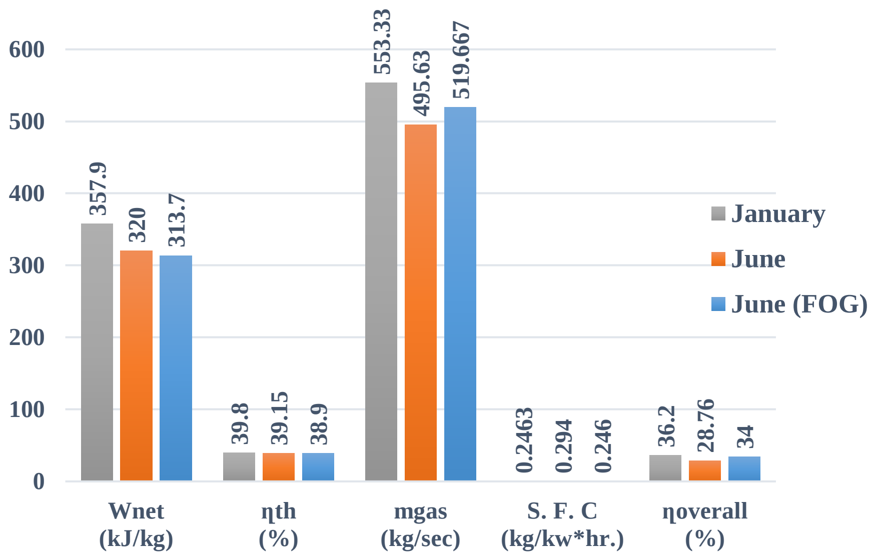

Fig. 4. A graph of the thermodynamic variables of a gas turbine unit for the January and June months.

4. Conclusion

In this research, the extent to which the thermal performance of the gas turbine unit at Zawia combined cycle power plant is affected by the air temperature for the two months of January and June, as one of the operating conditions of the gas turbine, was studied. To enhance the thermal performance of the plant's gas turbine unit, the inlet air cooling system for a compressor was used for June month through using a fogging system. The thermal performance of the unit was compared before and after using the fogging system. According to the results of the thermodynamic variables calculated for January and June at average ambient temperatures of 16^{o}C and 45^{o}C, respectively, the increase in ambient temperature leads to a decrease in the thermal efficiency, exhausting gas flow rate and overall electrical efficiency of the unit, and vice versa. In June, the thermal efficiency and overall electrical efficiency of each unit were 39.15% and 28.76%, respectively, while in January they were 39.8% and 36.2%, respectively.

The use of the 25% fogging cooling system enhanced and improved the thermal performance of the gas turbine unit in June, as the measured data and calculated values showed:

- The compressor inlet air temperature decreased from 318.15K to 301.6K, which resulted that decrease in the compressor outlet air temperature in a 4.1%.
- The network (W_{net}) decreased by 6.3kJ/kg.

- The specific fuel consumption (S.F.C) reduce by 0.048kg/kw hr.
- The overall electrical efficiency of a turbine unit increased by 5.24%.

5. References

1. P. K. Nag, Power plant engineering, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.
2. E. Kakaras, A. Doukelis, S. Karellas, Compressor intake-air cooling in gas turbine plants, Energy 29 (2004) 2347-2358.
3. H. Saravanamuttoo, G. Rogers, H. Cohen, and Straznicky, Gas Turbine Theory, New York: Prentice Hall, 2009.
4. E. Wafaa, effect of air temperature on the efficiency of gas turbines in Gerri power plant, 2010. ISSN (Print):1694-0784.
5. K. H. Kim, H. J. Ko, K. Kim, and H. P. Blanco, Analysis of water droplet evaporation in a gas turbine inlet fogging process, Applied Thermal Engineering. 2012: 33(34):62-69.
6. E. C. Wilcox and A. M. Trout, Analysis of thrust augmentation of turbojet engines by water injection at compressor inlet including charts for calculation compression processes with water injection, NACA Report No. 1006, 1951.
7. S. M. Arabi, H. Ghadamian, M. Aminy, H. A. Ozgoli, B. Ahmadi, M. Khodsiani, Simulation of a GEF5 Gas Turbine Power Plant Using Fog Advanced Cycle and a Systematic Approach to Calculate Critical Relative Humidity, Int. J. Eng. Trans. B Appl. 33(2020) 2356-2364. https://doi.org/10.5829/ije.2020.33.11b.26
8. T. Wang, and J. R. Kahn, DISCUSSION OF SOME MYTHS/FEATURES ASSOCIATED WITH GAS TURBINE INLET FOGGING AND WET COMPRESSION. Proceedings of ASME Turbo Expo 2012 GT2012 June 11-15, 2012, Copenhagen, Denmark.
9. N. J. Lamfon, Y. S. Najjar, and M. Akyurt, Modeling and simulation of combined gas turbine engine and heat pipe system for waste heat recovery and utilization, Energy conversion and Management, 1998 Jan 1;39(1-2):81-6**.**
10. B. Dawoud, Y. H. Zurigat, J. Bortmany, Thermodynamic assessment of power requirements and impact of different gas-turbine inlet air cooling techniques at two different locations in Oman. Applied Thermal Engineering. 2005 Aug 1;25(11-12):1579-1598.
11. S. Bracco, A. Pierfederici, A. Trucco, The wet compression technology for gas turbine power plant: Thermodynamic model, Applied Thermal Engineering, 2007; 27:699-704.
12. S. Sanaye, M. Tahani, Analysis of gas turbine operating parameters with inlet fogging and wet compression processes, Applied Thermal Engineering, 2010;30:234-244.
13. M. A. Ehyaei, A. Mozafari, M. H. Alibiglou, Exergy, economic & environmental (3E) analysis of inlet fogging for gas turbine power plant, Energy, 2011;36:6851-6861.
14. D. W. Shepherd, D. Fraser, Impact of heat rate, emissions and reliability from the application of wet compression on combustion turbines. Siemens AG; 2005. Available:http://www.energy.siemens.com/br/pool/hq/energy-topics/pdfs/gas-turbines-power-plants/5 Impact of Heat Rate.pdf (Accessed 2 January 2015).
15. M. M. Ammar, M. S. Hassan and Mohamed R. O. Ali, ENHANCEMENT OF GAS TURBINE PERFORMANCE BY USING FOGGING SYSTEM, Journal of Advanced Engineering Trends, Vol.43, No.1. January 2024. ISSN: 2682-2091.
16. E. K. Orhorhoro, and O. W. Orhorhoro, Simulation of Air inlet Cooling system of a Gas Turbine Power Plant. ELK Asia Pacific Journal of Applied Thermal Engineering. 2016; 1(2).
17. A. Z. Khalaf, A Study of the Operational Conditions Influence on the Performance of Kirkuk Gas Plant, Kirkuk University Journal/ Scientific Studies (KUJSS), Vol.10, Is.2, June2015, p.p(72-90). ISSN: 1992-0849.
18. A. Y. Cengel, A. M. Boles, Thermodynamics an engineering approach New York: McGraw-Hill, 2008.
19. M. A. Al-Mernaqi, T. L. Alfitouri, W. M. Esharif, Studying the impact of air temperatures on the efficiency of gas turbines and improve it at Zawia combined cycle power plant, a graduation project for a Bachelor's degree in mechanical engineering, Faculty of Engineering, Sabratha University, Spring 2021. (Arabic)