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The Impact of Climate on the Efficiency and Performance of the Qayyarah Gas Station

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Abstract: In this paper, We will attempt to study a fundamental problem, namely, how gas stations operate worse as the outside temperature rises and production decreases. This examination focused on the gas generator made at the Al-Qayyarah gas station. Based on the data from the station's fourth unit, it was discovered that the two factors that affect the compressor's theoretical efficiency, air temperature entering the device, and compression ratio, are strongly correlated. season is larger than summer because more concentrated energy is generated during the winter, reaching 107.5 MW, whilst concentrated energy production in the summer does not go over 85.8 MW, Due to the cold temperatures, efficiency in the winter was only 29%, while in the summer it was 27.2%.

Keywords: Environment Temperature, Power Plant Performance, Thermal Efficiency, Specific Fuel Consumption.

1. INTRODUCTION

One of the challenges the world faces is the energy problem. Energy sources are few, and demand for it has risen recently as a result of global economic expansion. This has forced nations to seriously consider how to meet their needs for energy, which have permeated all spheres of human existence. It is one of the most significant contributors to global warming, making it a pressing issue in every nation on earth. Because energy is essential to all facets of human use, including education, water purification, agricultural output, and environmental sustainability, it serves as the principal engine for social and economic progress. 1.7 billion individuals, between (1990 and 2010), and it is anticipated that demand will rise as a result of population growth. Moreover, numerous research have revealed a link between electric energy consumption and economic growth. This implies that rising human electric energy consumption has a direct impact on economic growth. More energy is stimulated by this

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economic growth [1]. The usage of alternative energy, also known as renewable energy and produced by natural processes, has become increasingly popular throughout the world. The most significant examples include solar energy, wind energy, water energy, nuclear energy, etc. Despite being a clean energy that does not harm the environment, unlike traditional energy, renewable energy is limited and cannot meet demand because of the harmful combustion products that damage the ozone layer, which in turn has a negative impact on both human health and the climate of the planet. One of the fundamentals of development is electric energy since it serves as the foundation for plans for industrial, commercial, agricultural, and service development. Like other developing nations, Iraq experiences a scarcity of electric energy, due to the demand for it in the final decade of the 20th century, which was not accompanied by the necessary increase in supply, which caused a deficit in the supply of electric power and a decline in the quality of electric power services. This hindered its development in the majority of areas of contemporary development [2] [3]. bThe consumption of electric energy has developed during the past years, so raising the efficiency of its production and rationalizing its consumption has become imperative to meet the increasing demand for it, and because of its positive reflection towards improving the environmental impact that reduces emissions that thus affect global warming as a result of the decrease in fuel consumed in thermal stations and the trend to Possibilities about replacing it with clean energy and reducing the use of fossil fuels and the comparison between them, which depends on the natural factors of the country on the one hand and the costs of the capabilities on the other hand, and fossil fuels are among the most important sources of electric energy production by converting thermal energy into electrical energy, as in gas turbines[4].

The gas turbine transforms the thermal energy contained in the hot gases that arise from combustion, which are produced by the gas unit's usage of compressed air and fuel, into mechanical energy (rotation). The T3 gas turbine converts the stored thermal energy as the atmospheric air travels from the air filters to the compressor of the device, raising the atmospheric pressure to about (17 bar), and then directing the compressed air to the combustion chamber where the fuel and air are mixed and ignited to produce hot gases. The mechanical energy from the gases is used to turn both the turbine shaft and the compressor and the pressure of the gases drops to almost atmospheric pressure or slightly above as the gases pass from the turbine outlet through the stack (Exhaust) to the atmosphere at a temperature of T4. At the same time, the main shaft of the air compressor rotates independently using mechanical energy as a result of the turbine's rotational motion. [5].

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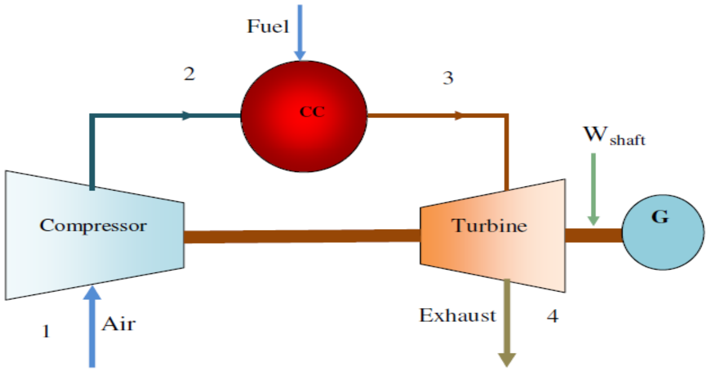

Fig. 1. Gas Turbine unit

By improving the simple cycle by adding intercooling, the researcher Thamir K. Ibrahim et al. [6] performed an analytical study of the gas turbine system (Joule-Brighton cycle), which increased the efficiency of the gas turbine when improved, and they demonstrated that the efficiency of the modified cycle is influenced by operating variables (ambient temperature, compression ratio, gas turbine inlet temperature. The work of the high-pressure gas turbine is limited to rotating the compressor, while the low-pressure gas turbine works to generate electricity using simulation (MATLAB), as we showed that the efficiency of the cycle and the energy produced decreases with the increase in pressure. The researchers, Thamir & Rahman [7], conducted a theoretical study of the modified Joule-Brighton cycle by adding a second gas turbine to it.

The researchers, Mohapatra & Sanjay [8] studied the modified Brighton cycle by adding a humidifier to the air entering the compressor and the effect of operating factors: ambient temperature, compression ratio, relative humidity, and turbine entry temperature. From the results, we showed that adding humidification to the air enhances performance by (4.84%). at high temperatures and low relative humidity, and we also showed that the total efficiency increases with the increase in the compression ratio.

The researcher Khalaf [9] conducted a study on the effect of operating conditions, compression ratio and compressor entry temperature on the thermal performance and specific consumption of the Kirkuk gas power station. Work was done on the generation unit (GT1) (Brighton simple cycle) with a design capacity of (70 MW), and the data was taken from the control system of the station. . It was concluded that the unit produces energy (30 MW) approximately in the summer, while it produces approximately (45 MW) in the winter, and this confirms that the high temperatures in the summer season negatively affect the performance, and this rise is a function of the compression ratio, which in turn increases the determinants of unit occupancy, and between Also, the temperature is directly proportional to the compression ratio, the higher the temperature difference on both ends of the compressor, a high compression ratio can be obtained and thus a high capacity. The researcher Ahmed et al. [10] studied the power and energy available for the gas power station located in the city of Kirkuk with a capacity of (150MW) by applying the first and second law of thermodynamics, as the data were taken from the station operation unit, the energy analysis was represented by the Sankey diagram, and they showed from the results that the total efficiency of the cycle It is inversely proportional to the

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ambient temperature, meaning that the higher the ambient temperature, the lower the efficiency, as the total thermal efficiency of the unit was 33.069%, while the results showed that the efficiency of the compressor, combustion chamber, turbine, and exhaust gases was 93.34%, 85.52%, 94.11%, and 42.32%, respectively. In the research described in this paper, electricity was produced using one of the gas generators installed at the Qayyarah power station. In both the winter and summer seasons, the exact energy produced as an indicator of performance will be compared to the actual efficiency. According to the field data collected by the Qayyarah Power Plant Operation and Control Department for the fourth unit operating on crude oil fuel, the Aspen Hysys software used for modeling this power station has high validity. The effectiveness and performance of the plant were evaluated after the simulation. In addition, how external influences affect plant performance.

2. MATERIALS AND METHOD

Powe Plant Component: Gas turbines run on either the simple (open or closed) cycle, known as the Brighton cycle, which has three components (a compressor, a combustion chamber, and a gas turbine), or the steam cycle, known as the Rankine cycle. The combined or combined cycle is more effective when the two cycles are used together. When opposed to steam turbines, one benefit of employing gas turbines is that they are quicker to set up and operate due to their light weight and ease of installation. This is especially true when the peak load lasts for several hours, the speed of operation and extinguishing, and their construction costs are low compared to other stations, and they are frequently used in the regions The desert, because it does not need water, and the temperature entering the turbine and the compression ratio are two factors affecting the efficiency of the gas turbine [12] As for the fuel, it can be natural gas, crude oil, or heavy gas. The waste heat from the exhaust can be used for the station's daily operations or by connecting it to another gas unit because the gases coming out of the exhaust carry significant thermal energy, but they also have an impact on environmental sustainability because they carry second gas. Carbon dioxide contributes to global warming and the production of harmful gases like sulfur dioxide (SO_2) and nitrogen oxides (NO_x). In the industrial sector, the demand for internal combustion engines to run machinery and produce electricity is also steadily increasing. Gas turbine seen in Figure 2. [13].

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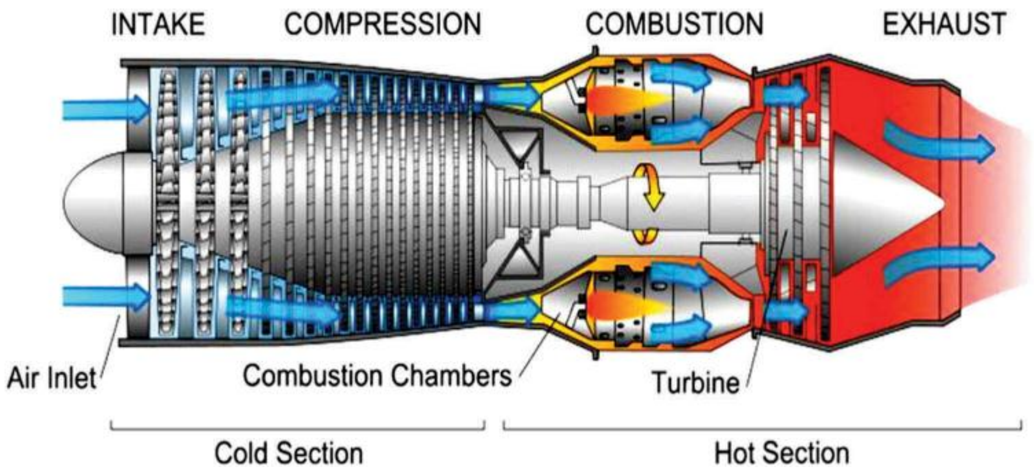

Figure 2. Gsa Turbine

The city of Qayyarah in Nineveh Governorate is the site of the Qayyarah gas power station, which was sought to conduct the research. Figure 2 shows the Qayyarah gas station, which is one of the strategic stations in northern Iraq. It was created by General Electric (GE) and used by Turkish companies. Six generators from Calic Energy Corporation can be found at the station. frame 9e This term is an acronym for its model series (9001E) Single shaft turbine specifications Engine speed (3000 rpm) Unit designed to operate at 125 MW Design power for operation at load (100 MW) approx. Designed for open cycle operation and using three different fuels (crude oil, natural gas and light fuel), on March 2014, and started working at the station [14].

Figure 3**.** Qayyarah gas power station [14]

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POWER PLANT FIELD DATA

The Operations and Control Department, which is in charge of capturing all data from the gas turbine unit, provided the field data for the 2022 gas turbine unit. There were just two months used: July in the summer and January in the winter. This study made use of field data for a gas turbine unit that burns crude oil (UNIT GT4 - frame 9E). This experimental field data was gathered, and Table 1. contains a description of it. The mean values of the daily operating average variables were derived after analysis. where liquid crude oil serves as the engine's primary fuel.

Table 1. field data of GT4[14]

Operating parameters	UNIT	January	July
Active. power	MW	96.8	82.4
Inlet air RH	%	43	12
Mass of air	kg/s	264	202
T1	°C	2	45
P1	kPa	101.3	101.3
T2	°C	302	357
P2	kPa	911.7	911.7
flow rate fuel	kg/s	7.2	6.4
Temperature fuel	°C	65	70
Pf	Bar	5.4	5.2
P3	kPa	911.64	911.64
T3	°C	1054	1103
T4	°C	485	518
Pressure ratio		9.8	9.1
Cpa	kJ/kg K	1.005	1.005
Cpg	kJ/kg K	1.15	1.15

Gas Turbine Simulation Using Aspen Hys

The HYSYS software was created by Hyprotech before being bought by AspenTech and transformed into Aspen HYSYS. Due to the fact that it has all the industrial units required for the majority of industries, the HYSYS program is used to model oil, natural gas, petrochemical, gas, and thermal facilities. The program also includes a comprehensive database with the majority of the materials used in the aforementioned industries with the option to add additional materials or compounds. It is also used in the design of industrial units like reactors, distillation towers, absorption columns, heat exchangers, and many, many other industrial units [15]. The HYSYS program is used to create a full design for petroleum refining plants, as well as gas plants and petrochemical plants, and it is used in design (along with other auxiliary programs) by major design firms like Enppi and others, whether in the Arab world or elsewhere in the world. The program also performs the necessary calculations from the calculations of the various parameters. The program also chooses the best operating parameters in terms of temperatures, pressure, heat quantity, and production rate, which can produce the most profit for the facility with the fewest costs [16].

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DCS control units can also be simulated using the HYSAS application. The program is additionally employed to research shifting operational conditions. With regard to production rate, we differ in that we first simulate the unit whose operating conditions we wish to change using the HYSAS program, after which we gradually alter the settings and analyze the effects of this change on production rates [17].
The HYSAS program is a flexible and reliable process simulation that is built on the fundamental principles of integration and innovation. It offers HYSAS users a number of significant benefits, including the most recent chemical process technologies, unified functions in a single software environment, seamless connection to the chemical engineering computing environment with tool links like MS Excel and Word and interfaces like (COM, DCOM), and HYSAS combines a cutting-edge graphical user interface. The software can also be modified to support unique thermodynamics, unit operations, calculations, and reporting. both dynamic and steady state systems are simulated [18]. As illustrated in Figure 4. a straightforward gas turbine simulation model is constructed. The model is composed of three basic components: a compressor, a combustion chamber, and a turbine. Conditions under which air enters the compressor change during the four seasons of the year.

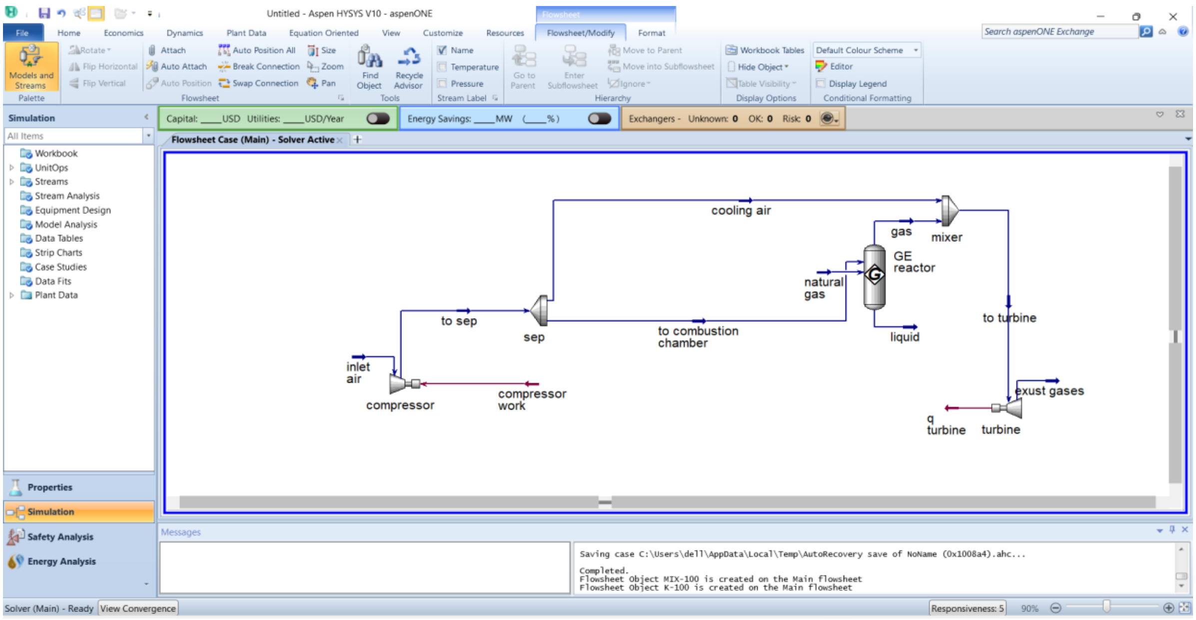

Figure 4. Flowchart for a basic Aspen HYSYS gas turbine model

Simulations were performed using the HYSYS program for the fourth unit that operates on crude oil fuel, to determine the differences in gas turbine performance and efficiency and to predict the range of production and performance under different operating condition. The simulation was conducted under the following presumptions: that all cycle processes are constant over time; that atmospheric pressure is the standard pressure of (1.01325 bar), which is the same pressure as the air entering the compressor and exiting the exhaust; and that the temperature of the incoming air is identical to that of the surrounding atmosphere. The introduction of air, fuel, combustion products, and ideal gases, subject to all ideal gas laws,

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while ignoring the values of the change in kinetic and latent energy at the entry and exit of each station component (compressor, combustion chambers, gas turbine), due to their small value in comparison to the change in enthalpy, adding pressure to the incoming air The pressure of the gases leaving the combustion chamber can be calculated, and it is equal to (0.97 * P2), and the imposition of each component of the cycle, which includes the compressor, combustion chamber, and other components, results in nitrogen coming to the compressor and coming out of it with molar ratios of 79% and oxygen only 21%, assuming a decrease in the pressure of the outputs of the gases leaving the combustion chamber by 2% of the pressure of the air entering it, The turbine and compressor have a mechanical efficiency of 95% [19][20].

Theoretical Equations Of Gas Turbine Unit Performance Parameters

The compressor's pressure outlet can be evaluated as: [21]

$$P_2 = rpc * P_1 \quad (1)$$

It is possible to calculate the ideal isentropic temperature as:

$$T_2 = T1\ (P_2/P_1)_a - 1/\gamma_a \quad (2)$$

The mass flow rate is calculable as:

$$\dot{m} = \rho_a VA \quad (3)$$

It is feasible to evaluate the work compressor's as: [22]

$$W_c = \dot{m}_a\, Cp(T_2 - T_1) \quad (4)$$

the following is a representation of the actual combustion equation as: [23]

$$\lambda C_{x1}H_{y1} + (X_{o2}O_2 + X_{N2}N_2 + X_{H2O}H_2O + X_{CO2}CO_2) \rightarrow$$
$$Y_{CO2}CO_2 + Y_{H2O}H_2O + Y_{O2}O_2 + Y_{N2}N_2 \quad (5)$$

The combustion chamber's mass inflow is evaluated as:

$$\dot{m} = \lambda\, \dot{m}_a\, Mf/Ma \quad (6)$$

This is an estimate of how much gas enters the gas turbine: [24]

$$\dot{m}_g = \dot{m}_f + \dot{m}_a \quad (7)$$

The combustion chamber's additional heat can be calculated as: [25]

$$\dot{Q}_{cc} = \eta_{cc}\, .\, \dot{m}_g\, .\, Cp_g\, (T_3 - T_2) \quad (8)$$

the ideal temperature for gas turbine exhaust can be evaluated as:

$$T'_4 = T_3\, (P_4/P_3)_g - 1/\gamma_g \quad (9)$$

The equation below can be used to determine the temperature of a gas turbine's exhaust gas outlet:

$$T_4 = T_3 - \eta_{isGT}\, (T_3 - T_4) \quad (10)$$

The gas turbine's Work done can be evaluated as follows: [26]

$$\dot{W}_{GT} = \dot{m}_g . Cp_g\, (T_3 - T_4) \quad (11)$$

The Turbine's network exit can be calculated using:

$$\dot{W}_{net} = \dot{W}_{GT} - \dot{W}_c \quad (12)$$

Thermal efficiency can be calculated as:

$$\eta_{th\ GT} = \dot{W}_{net} / \dot{m}_f . LHV \quad (13)$$

For fuels, specific fuel consumption (SFC) can be calculated as: [27]

$$SFC_{\ GT} = \dot{m}_f * 3600 / \dot{W}_{net}\ , \quad (14)$$

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The modest (G.E frame 9E) gas Turbine unit at the Al-Qayyara gas power plant served as the technological foundation for the current investigation (Iraq). The simple gas Turbine unit at the Al-Qayara gas power plant consists of a single 14-stage compressor with a compression ratio of 1:12 that operates on the atmospheric pressure of the air to the combustion chamber. The compressor is powered by some of the mechanical work done by the gas turbine.

3. RESULTS AND DISCUSSIONS

By briefly presenting the data collected from the Qayyarah gas station's first unit's central control unit, which was stored in the Excel program, and contrasting it with the outcomes of the HYSAS software, as shown in Table 1. In order to analyze the impact of the air temperature entering the compressor on the performance of the unit in detail, the data were chosen taking into account the peak summer temperature of 45 degrees Celsius and the lowest temperature in winter of 2 degrees Celsius. The relationship between the temperature of the air entering the compressor and a particular amount of fuel consumption is shown in Fig. 5. (SFC). We take notice of the extent to which operational conditions near to design conditions have an impact on the particular fuel consumption, as the figure approaches (0.2725) kg/kw.hrduring the winter. During the summer, it increases to 0.2895 kg/kw.hr. The cause for this rise is the decline in power produced by the gas unit. The high fuel consumption is one of the drawbacks of relying on this type of turbine in locations with a hot environment, and it is consistent with some other research [27] [28].

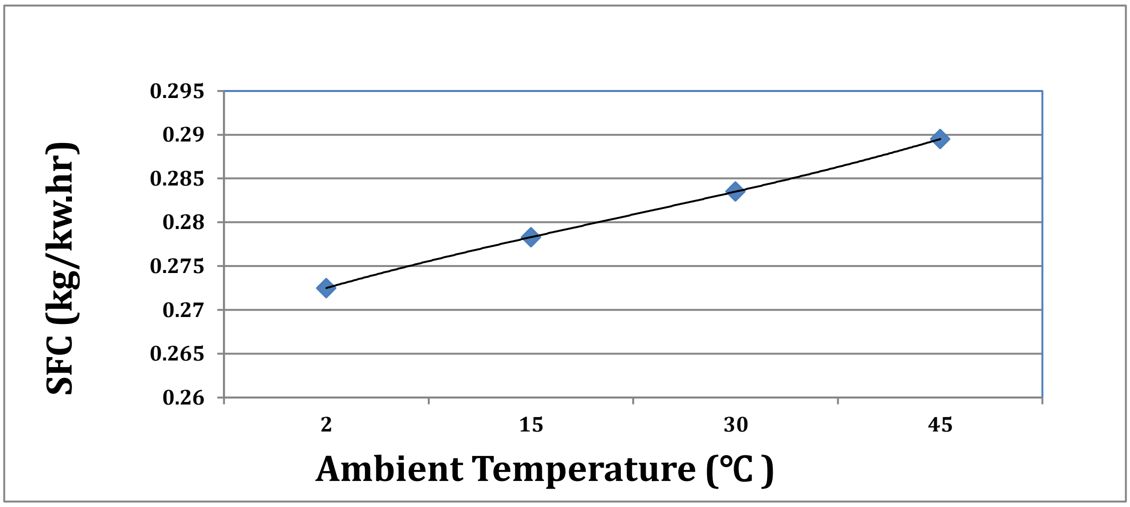

Fig. 5. SFC with ambient temperature.

The relationship between actual thermal efficiency and ambient temperature is shown in Fig. 6, where actual thermal efficiency, The winter season's high energy efficiency at the beginning of the year, when the temperature was (2°C), reaching (29%), and the summer season's decrease in efficiency to (27.2%), when the temperature was (27.2%), can be seen in the relationship between the simple gas unit's thermal efficiency and the change in the external environment's temperature. The temperature is (45°C), and the higher thermal efficiency during the winter is

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caused by the cooler air entering the compressor. The process of compressing the air entering the high-density compressor occurs as the air density rises, increasing the mass flow of air that requires more fuel to accomplish. The gas turbine's generating capacity is increased by the combustion process, increasing the system's thermal efficiency.

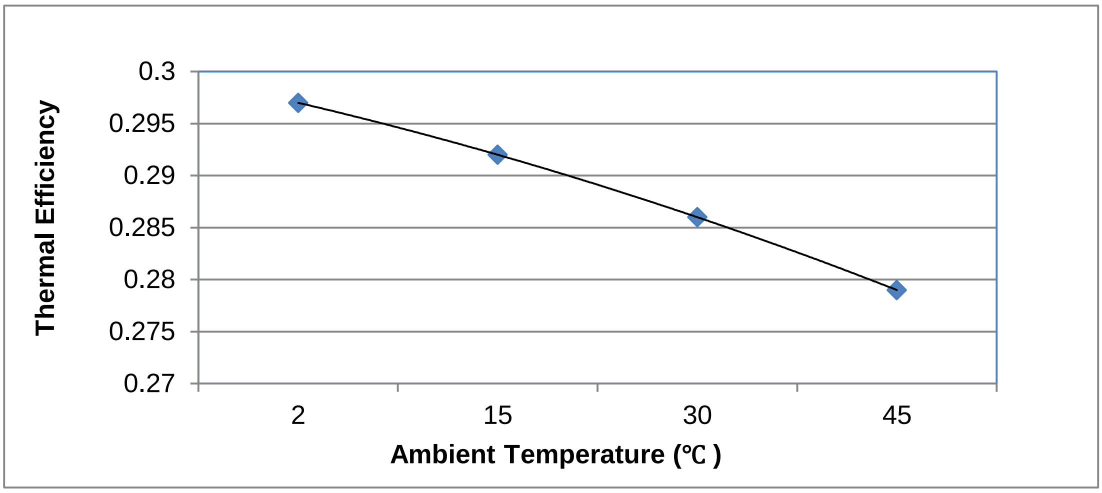

Fig. 6. Thermal efficiency with the ambient temperature.

The station's design criteria govern the temperature conditions inside the compressor, which in turn influences the compression ratio, which in turn has the most effect on performance, In comparison to the summer months, when the temperature is high and the load is low, the efficiency is higher during the winter season when the load is higher while the temperature is low. As a result, the air entering the compressor is highly compressed, which increases the mass flow of air and necessitates the use of additional fuel. to finish the combustion process and so boost the gas turbine's producing capacity, Fig. 7 illustrates this by showing how energy production decreases throughout the summer while increasing during the winter.

Fig. 7. Power output with ambient temperature..

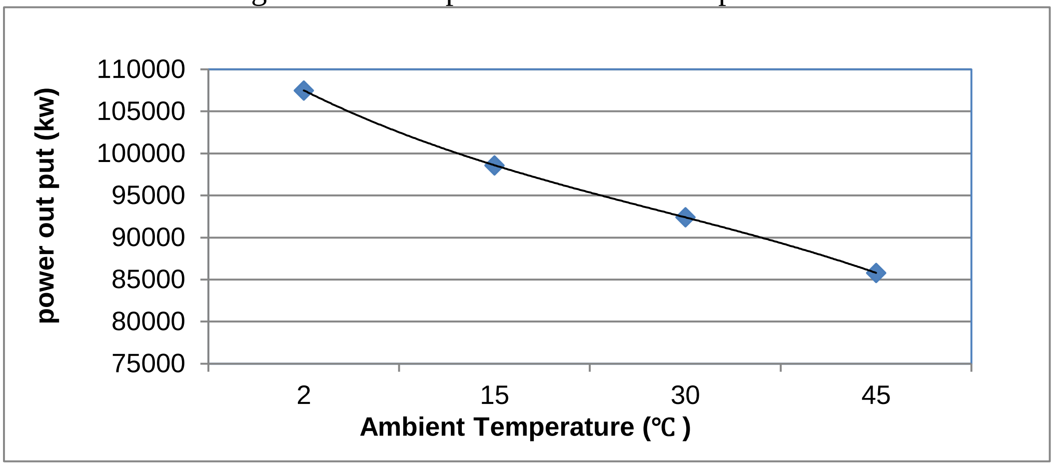

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Figure 8. illustrates how the temperature of the ambient temperature affects the amount of air that enters the gas unit's compressor. As can be seen from the graph, the amount of air fell by 13.8 percent as the outside temperature rose from 2 °C to 45 °C. Because the mass of air entering the compressor is impacted by the air density, which drops as the outside temperature rises.

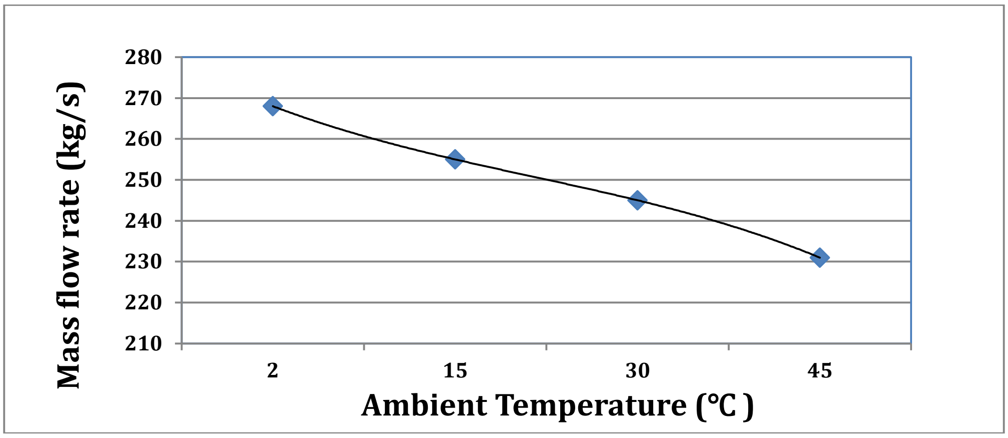

Fig. 8. the mass flow rate of air at the ambient temperature.

According to Fig. 9, when the ambient temperature increases from 2 °C to 45 °C, the temperature of the exhaust gases increases from 476 °C to 528 °C. This graph shows how the temperature of the waste gases varies depending on the outside environment. Due to the drop in gas turbine occupancy, exhaust gases are warmer than they would be under ideal circumstances. This has a negative effect on the exhaust gas temperature.

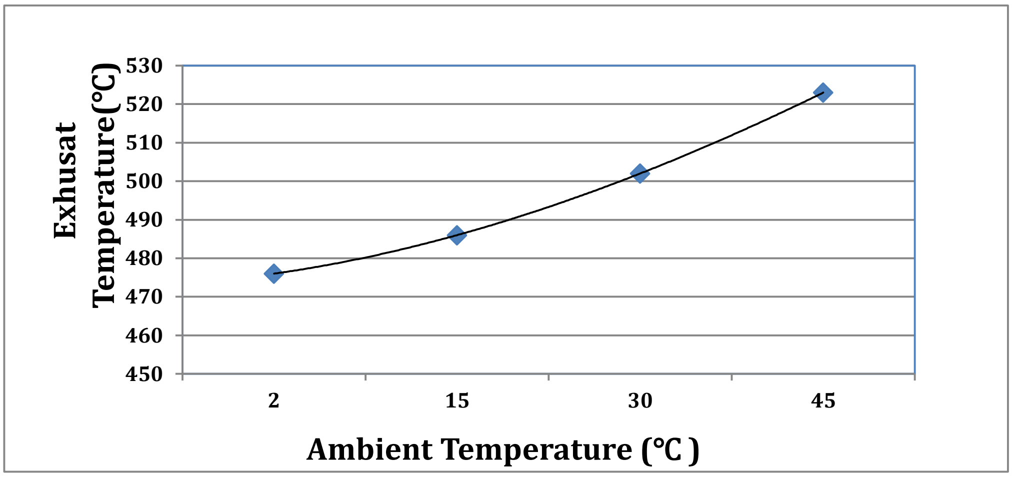

Fig. 9. Exhaust temperature with ambient temperature.

Figure 10 shows how the compressor's pressure ratio affects the gas turbine's power output. It is significant to remember that increasing compression ratio will improve power production and increase thermal efficiency. This is due to the fact that larger pressure ratios raise the

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maximum turbine inlet temperature (TIT), which in practice is around 1300°C and "must not exceed the temperature that the turbine blades "can bear." As a result, the turbine inlet temperature rises as it approaches the ideal level and then begins to fall. As a result, the useful pressure ratio range is 5 to 20.

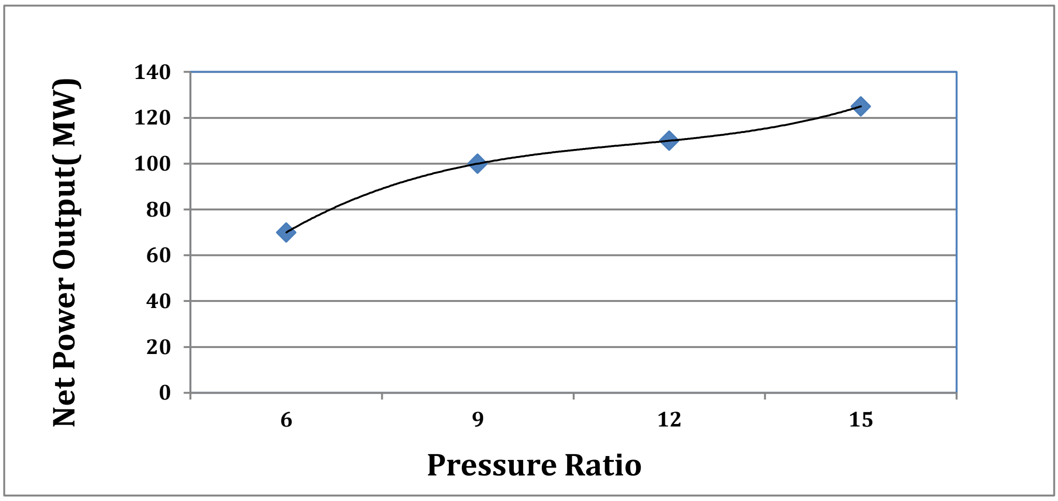

Figure 10. Impact of pressure ratio on power output.

4. CONCLUSIONS

The performance of Al-Qayyara gas stations has been examined in this research in relation to changes in the ambient temperature. The results of this investigation can be summed up as follows:
1. The specific fuel usage increases as the ambient temperature rises.
2. Thermal efficiency declines as ambient temperature increases.
3. The output power decreases as the ambient temperature increases.
4. The mass flow rate of air decreases as the ambient temperature increases.
5. The exhaust temperature increases together with the ambient temperature.

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