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The Effect of The Change In The External Environment Temperature On The Performance of Al-Qayyara Gas Station

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Abstract — *In this paper, we will try to study a basic problem, which is the decrease in the performance of the gas stations with the increase in the temperature of the external environment, and with the presence of a lack of production. This study was conducted on one of the gas units produced at Al-Qayyarah gas station to generate electric power. The results based on the data for the first unit of the station proved that the theoretical efficiency of the unit is a function of the two variables, namely the air temperature entering the compressor and the compression ratio and there is a close correlation between the two variables. As the compression ratio is directly proportional to the incoming air temperature, so when choosing the network of the unit as a measure of performance and calculating the efficiency, the efficiency in the summer season is greater than in the winter due to the marked decrease in the compressor operation. It was observed choosing the specific energy produced as a measure of performance, and the actual efficiency in the winter season is greater than summer because the specific energy produced in the winter season is greater as it reaches 114.5 MW while it does not exceed 88.1 MW in the summer season.*

Keywords — *Gas unit; environment temperature; gas turbine performance.*

I. INTRODUCTION

The simple gas unit consists of three main parts, which are the compressor, the combustion chamber, and the gas turbine, as shown in Fig. 1. It comes out at point 2 conditions at a temperature that depends on the ambient temperature and the compression ratio, to enter the combustion chamber and mix with the fuel to come out at point 3 conditions at a design temperature of 1200 ºC, after which the turbine enters the gases to expand the energy isentropic lost to the turbine axis to exit at the point conditions 4, Where two procedures with pressure stabilization and two procedures with entropy stability are performed. The expansion of the gases in the gas turbine results in mechanical work, which is converted by the electric generator into electrical energy.

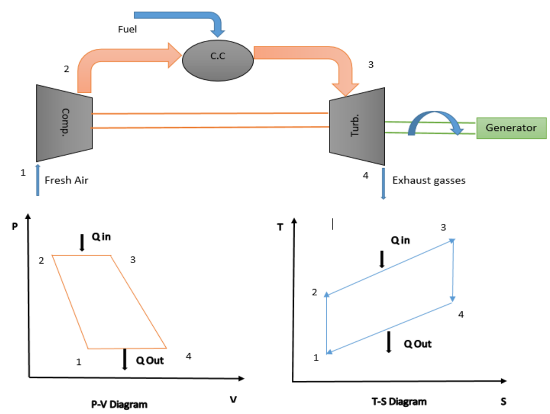

Fig. 1. Sample of the gas unit

The study includes the effect of external ambient temperature on the performance of the first unit GT1 in the Qayyarah gas station, and the unit is designed to work with a load of 125 MW as a design power to operate with a load of 115 MW as operating power according to the recommendations of the manufacturer (General Electric. It consists of six gas units, where the unit capacity is 125 mica). A total of 750 megawatts. This gas unit works with a simple cycle and one axis that is directly connected from the compressor side to the generator. Thus, the unit includes the following basic parts: an axial air compressor, a double ring combustion chamber, an open system gas turbine for cooling the blades by air, and then After that, the electric generator The main problem of the simple cycle gas generating units is their relatively low thermal efficiency [1-5].

A scientific and theoretical study was conducted by Dawood [6] on the effect of high ambient temperature on the performance of gas units. Various techniques have also been used to improve performance by using compression freezing, absorption, and cooling systems using steam, and it was found that the best performance of the unit is at 8 °C. Ashley studied [7] the effect of ambient conditions on the performance of gas units and it became clear that the energy produced is a function of the temperature of the air entering the compressor. Maher Saab [8] also studied the effect of the incoming air temperature on the performance of the gas units. It was found that the heat transfer coefficients of the gas, the flow rate of the working fluid mass, the amount of heat acquired, and the gas pressure drop were reduced when the generating capacity of the gas unit decreased.

A study was also conducted by Boiley [9] on the performance of gas units and the possibility of utilizing the heat involved in generating steam and using it to reduce the inlet air temperature to 10°C, which would improve the cycle performance. The researcher [10] studied the performance of the simple gas unit and the possibility of exploiting the heat presented in a combined cycle, as well as the effect of the air temperature entering the compressor on the temperature presented, and found that the best suitable conditions are at 16 °C.

As for al-Rubaie [11], he studied the possibility of exploiting the heat put into operation. Reverse osmosis desalination unit and it was found that 421 ton/year.MW of fuel could be saved if the gas unit was replaced by a thermoelectric center. Ismail [12] also studied energy economics resulting from mixing the two types of diesel fuel and heavy fuel and proved that it is the best mixing ratio when mixing 60% of diesel fuel with 40% of heavy fuel, but that is at the expense of combustion efficiency.

Shahd [13] studied the evaluation of the performance of the composite gas units using the steam injection technique and found that the application of the system of generating units installed on the simple gas unit leads to a clear increase in both the generating capacity and the thermal efficiency and that the amount of this increase in her research is 59.195 and 59.133% For its counterparts in the simple gas unit, respectively, and at an outdoor temperature of 15°C. The temperature that is put into the atmosphere at a temperature of 450°C to 550°C if it is used in a combined cycle to exploit energy or return this heat to heat the air coming out of the compressor, thus saving the amount of fuel entering the combustion chamber [14]. Howard [15] concluded that adding 100 ppm of zirconium to HFO could improve combustion efficiency by 2.2%. Recent years have been marked by an increase in the use of gas stations.

In this paper, it was conducted one of the gas units produced at Al-Qayyarah gas station to generate electric power. It will compare the specific energy produced as a measure of performance and the actual efficiency in the both winter and summer season.

II. SIMULATION OF THE GAS UNIT

The simple gas unit was simulated using the Engineering Equation Solver program, which is considered one of the modern programs in the field of mechanical engineering and contains a database of the physical properties of all fluids such as (enthalpy, density, thermal conductivity) and others. The current research has depended on the technical specifications and operating conditions of the simple (GE frame 9e) gas unit in the Qayyara gas station (Iraq).

The simple gas unit in the Qayara gas station consists of a single compressor consisting of 14 stages working on the atmospheric pressure of the air to the combustion chamber with a compression ratio (1:12), where the compressor is driven by part of the mechanical work performed in the gas turbine.

The pressure outlet from the compressor can be evaluated as [16]:

$$P_2 = r_{pc} * P_1 \qquad \ldots(1)$$

The perfect isentropic temperature can be estimated as:

$$\acute{T}_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma_a - 1}{\gamma_a}} \qquad \ldots.(2)$$

And the actual temperature of air exit from the compressor can be found as:

$$T_2 = T_1 \left\{1 + \frac{1}{\eta_{isc}}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma_a - 1}{\gamma_a}} - 1\right]\right\} \qquad \ldots(3)$$

The work of the compressor can be evaluated as [16]:

$$\dot{W}_c = \dot{m}_a C_{pa}(T_2 - T_1) \qquad \ldots(4)$$

The air density may estimate as:

$$\rho_a = \frac{P}{R_g T} \qquad \ldots(5)$$

The mass flow rate can be evaluated as:

$$\dot{m}_a = \rho_a V A \qquad \ldots(6)$$

The actual combustion equation can be represented as [17]:

$$\lambda C_{x1} H_{y1} + (X_{o2} O_2 + X_{N2} N_2 + X_{H2O} H_2 O + X_{CO2} CO_2) \rightarrow Y_{CO2} CO_2 + Y_{H2O} H_2 O + Y_{O2} O_2 + Y_{N2} N_2 \qquad \ldots(7)$$

And the mass inlet to the combustion chamber is estimated as:

$$\dot{m}_f = \frac{\lambda \dot{m}_a M_f}{M_a} \qquad \ldots(8)$$

The amount of gas inlet to the gas turbine is evaluated as [18]:

$$\dot{m}_g = \dot{m}_f + \dot{m}_a \qquad \ldots(9)$$

The heat added to the combustion chamber can be evaluated as:

$$\dot{Q}_{cc} = \eta_{cc} \,.\, \dot{m}_g \,.\, C_{pg}\,(T_3 - T_2) \qquad \ldots(10)$$

The perfect temperature of exhaust gas from gas turbine

$$\acute{T}_4 = T_3 \left(\frac{P_4}{P_3}\right)^{\frac{\gamma_g - 1}{\gamma_g}} \qquad \ldots(11)$$

To calculate the temperature of the exhaust gas outlet from a gas turbine, the following equation is:

$$T_4 = T_3 - \eta_{is} GT\ (T_3 - \acute{T}_4) \quad \dots(12)$$

The work done from the gas turbine can be estimated as:

$$\dot{W}_{net} = \dot{m}_g \,.\, C_{pg}\ (T_3 - T_4) \quad \dots(13)$$

The network exit from the turbine can be calculated as:

$$\dot{W}_{net} = \dot{W}_{GT} - \dot{W}_c \quad \dots(14)$$

The power generated is represented as:

$$Pe_{GT} = \dot{W}_{net} * \eta_m GT \quad \dots(15)$$

Thermal efficiency can be evaluated as:

$$\eta_{th\ GT} = \frac{Pe_{GT}}{\dot{m}_f \,.LHV} \quad \dots(16)$$

Specific fuel consumption (SFC) for fuel can be estimated as:

$$SFC_{\ GT} = \frac{\dot{m}_f * 3600}{Pe_{GT}} \quad \dots(17)$$

The simple gas unit was simulated using the Engineering Equation Solver program, which is considered one of the modern programs in the field of mechanical engineering and contains a database of the physical properties of all fluids such as (enthalpy, density, thermal conductivity) and others.

The current research has depended on the technical specifications and operating conditions of the simple (GE frame 9e) gas unit in Al-Qayyara gas station (Iraq). The simple gas unit in Al-Qayara gas station consists of a single compressor consisting of 14 stages working on the atmospheric pressure of the air to the combustion chamber with a compression ratio (1:12), where the compressor is driven by a part of the mechanical work performed in the gas turbine [19].

III. RESULTS AND DISCUSSION

Through a brief presentation of the recorded data from the central control unit of Al-Qayyarah gas station, the first unit, which was stored in an Excel program, and compared with the results obtained from the engineering equations solution program, as in Table (1). The data was selected in light of the highest temperature in the summer is 55 °C and the lowest temperature in the winter is 5°C to study the effect of the air temperature entering the compressor on the performance of the unit in detail

Fig. 2 represents the relationship between the air temperature entering the compressor and the specific fuel consumption (SFC). We note the extent of the impact of the operational conditions when close to the design conditions on the specific fuel consumption, as the value reaches (0.2382) KG / KW.H in the winter season. In the summer it rises to (0.2605 KG / KW.H). The reason for this increase is the decrease in the power generated in the gas unit, and the high fuel consumption is one of the disadvantages of relying on this type of turbine in geographical areas with a hot climate and is consistent with some previous studies.

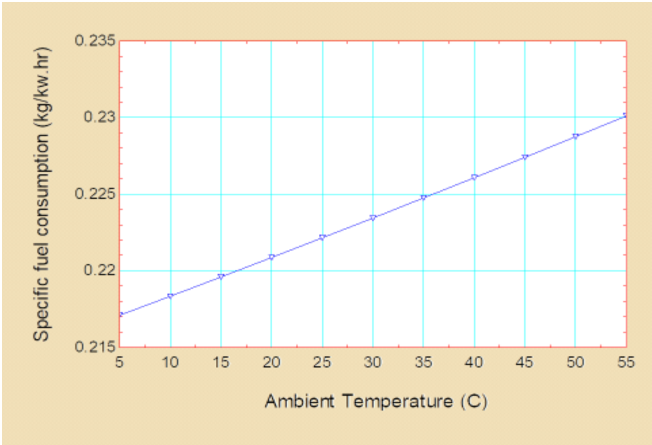

Fig. 2. Specific fuel consumption with ambient temperature.

Fig. 3 shows the relationship between the real thermal efficiency and the ambient temperature as the real thermal efficiency is the true measure of the turbine performance, which is equal to the quotient of dividing the amount of energy produced by the fuel consumed according to equation (6) that the real efficiency of the turbine in the winter is much better than It is in the summer by a very clear margin. In the summer, the efficiency in the morning periods is high and close to its values in the winter season, due to the low air temperatures during the early morning periods [20].

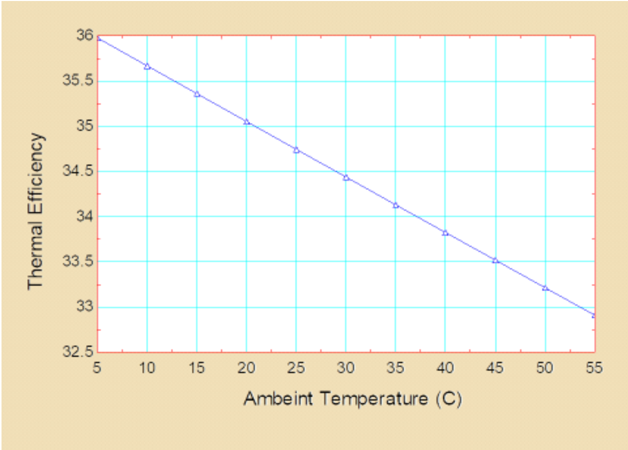

Fig. 3. Thermal efficiency with ambient temperature.

The design specifications of the station determine the temperature conditions of entering the compressor, and this determination leads to later determining the compression ratio, which in turn has the greatest impact on the performance. Therefore, it is expected to obtain a high compression ratio whenever the temperature difference at the two ends of the compressor is high. Consequently, higher capacity and this can be seen in Fig. 4 as the amount of energy produced in the summer season decreases, while in the winter season it is higher, and to obtain a high compression ratio, a high workload must be spent on the axis of the compressor, and this work is the determinant of the theoretical efficiency.

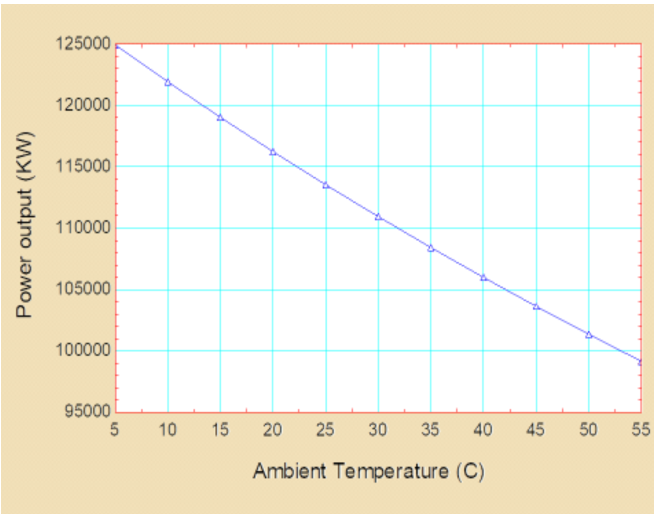

Fig. 4. Power output with ambient temperature.

Fig. 5 shows the effect of the change in the temperature of the outside environment on the air mass entering the compressor of the gas unit, as it is noticed through the graph that the air mass decreased by (15.27)% when the temperature of the outside environment increased from 5 ° C to 55 ° C as a result Because the air density decreases when the outside temperature rises, and this, in turn, affects the mass of air entering the compressor [20].

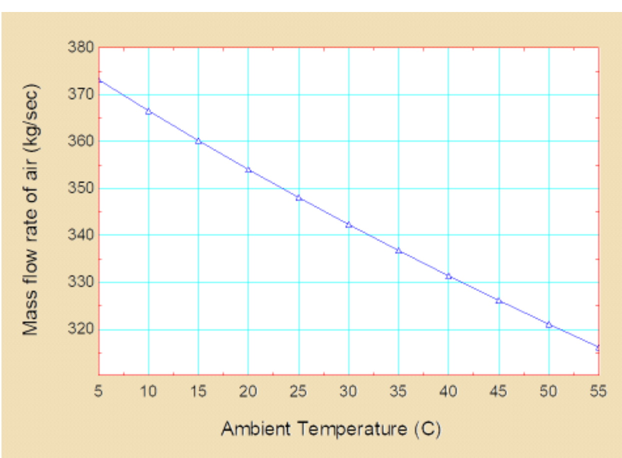

Fig. 5. The mass flow rate of air with ambient temperature.

Fig. 6, it shows the effect of the increase in the temperature of the outside environment on the temperature of the waste gases, as the temperature of the exhaust gases increases from 505 ° C to 574 ° C when the environment temperature rises from 5 ° C to 55 ° C. Exhaust gases, due to the decrease in the gas turbine occupancy, which negatively affects the temperature of the exhaust gases, making it higher than it is at standard conditions.

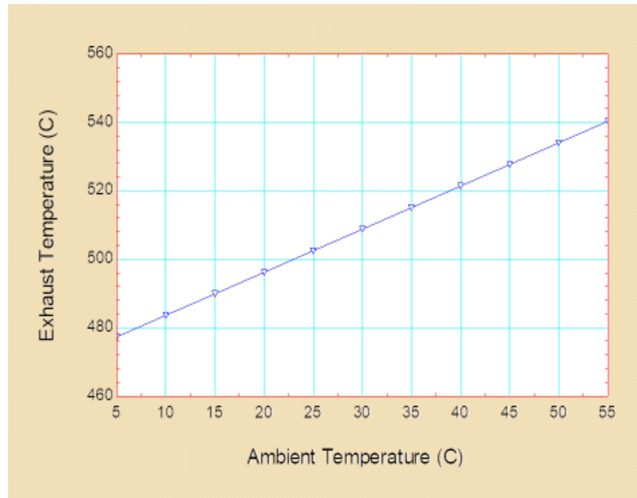

Fig. 6. Exhaust temperature with ambient temperature.

VI. CONCLUSIONS

This paper has investigated the effect of the change in the external environment temperature on the performance of Al-Qayyara gas stations. The conclusions of this study can be summarized as:

1. The specific fuel consumption is increased with the increasing ambient temperature.
2. The thermal efficiency is decreased with the increasing ambient temperature.
3. The output power is reduced with increasing ambient temperature.
4. The mass flow rate of air is decreased with increasing ambient temperature.
5. The exhaust temperature is increased with increasing ambient temperature.

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