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THE INFLUENCE OF AMBIENT TEMPERATURE ON THE GAS TURBINE POWER PLANT PERFORMANCE

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ABSTRACT: - In this paper a computer program is employed to evaluate the performance of a gas turbine power plant at a different ambient temperature. This is very important especially in Iraq, because of the wide range of ambient temperature variation throughout the year. The results show that the thermal efficiency of the plant decreases as the ambient air temperature increases, where the drop in efficiency is significant at higher temperatures, especially in summer season. So, it is very important to use a cooling system to control the ambient temperature for best performance. The study is done on a single shaft, simple cycle gas turbine power plant with maximum output power of 20 MW.
Key Words: ambient temperature, thermal efficiency, gas turbine power plant, performance.

1- INTRODUCTION

Gas turbines have been used for electricity generation in most countries around the world. The economics of power generation by gas turbine is proving more attractive in all parts of the world due to its low capital cost, high reliability and flexibility in operation. Another outstanding feature of gas turbine plant for power generation is capability of quick starting and capability of using wide variety of fuels from natural gas to residual oil or powdered coal. The gas turbine power plant nowadays is universally used as peak load, base load as well as stand by unit due to its outstanding operational characteristics. [1,2]

In Iraq, gas turbine recently used to produce electricity to meet the required energy demand. The average efficiencies of gas turbine in Iraq over the last five years was in the range of (20-28)%, such low efficiencies can be attributed to many reasons, such as operation mode, poor maintenance, engine size and age.[3]

The cost of produced electricity and gaseous emissions that would otherwise arises from conventional generators could be reduced by employing a hybrid system that uses a renewable energy source, such as solar energy [4, 5].

2. THEORY AND PERFORMANCE MODELING

The gas turbine essentially consists of compressor, combustion chamber and turbine as shown in fig (1).The air is compressed in a compressor and the fuel is burned in the combustion chamber when the compressed air is supplied from the compressor. The burned high temperature gases are passed through turbine. The part of the work developed by the gases passing through the turbine is used to run the compressor and remaining (30-35) % is used to generate the electrical energy. Fig (2) shows the processes of the cycle.

2.1- GAS TURBINE UNITE

The cycle is single shaft, simple cycle pressure ratio of (12) air flow rate is (70 Kg/sec) and inlet pressure (100 KPa) and the estimated power output (20 MW).

2.2- COMPRESSOR

The compressor is axial with (15) stages and (5200 rpm). The pressure ratio is (r_p =12) and the specific heat ratio (K=1.4) and specific heat of the air (C_{pa}=1.005 KJ/Kg ^{0}C) The pressure of the air leaving the compressor can be determined by equation:

$$\frac{P_2}{P_1} = r_p \ldots\ldots\ldots (1)$$

The isentropic efficiency of the compressor is (ζ_s = 0.88) and the isentropic outlet temperature is determined from the equation:

$$\frac{T_{2s}}{T_1} = \left(r_p\right)^{\frac{k-1}{k}} \ldots\ldots.. (2)$$

Actual temperature is calculated from the definition of isentropic efficiency:

$$T_{2a} = \frac{T_{2s}}{\zeta_s} \ldots\ldots\ldots (3)$$

The actual work of the compressor is given by:

$$W_c = m_a Cp_a \left(T_{2a} - T_1\right) \ldots\ldots\ldots (4)$$

2.3COMBUSTOR

The heat input to the combustor can be determined from the following equation

$$Q_{in} = m_a Cp_g \left(T_3 - T_{2a}\right) \ldots\ldots\ldots (5)$$

Where Cp_g specific heat of the flue gases =1.15 KJ/Kg.^{0}C and efficiency of combustion is $\left(\eta_{comb} = 0.98\right)$, fuel air ratio $\left(f = \frac{m_f}{m_a}\right)$

and $m_f = \dfrac{q_{in}/LHV}{\eta_{combustion}} \ldots\ldots\ldots (6)$

Where:

f : fuel to air ratio

m_f : mass of fuel.

q_{in} : heat supply y the fuel in the combustion chamber.

LHV : low heating value of fuel.

2.4 TURBINE:

The power produced by the by the turbine is determined as following

$m_t = m_a + m_f \ldots\ldots\ldots (7)$ where m_t : total mass of hot gases.

η_{turbine}=0.88

The expansion ratio is given by

$$r_p = \frac{P_4}{P_3} \ldots\ldots\ldots (8)$$

$$T_{4s} = T_3 \left(r_p\right)^{\frac{k-1}{k}} \ldots\ldots.. (9)$$

$$T_{4a} = T_{4s}\ \eta_{\text{turbine}} \ldots\ldots\ldots (10)$$

$$W_T = m_t Cp_g \left(T_3 - T_{4a}\right) \ldots\ldots\ldots (11)$$

Finally the thermal efficiency of the cycle is determined by:

$$\eta_{th} = \frac{W_{net}}{q_{in}} \quad \text{.........} \ (12)$$

The net work done

$$W_{net} = W_T - W_C \quad \text{.........} \ (13)$$

3-RESULTS AND DISCUSSION

The influence of ambient temperature on the thermal performance of gas turbine cycle power plant is investigated. The effects of the ambient temperature on the output power, thermal efficiency, heat rate, exhaust flow and exhaust temperature are determined and presented.

Figure (4) shows the relation between output power and ambient temperature, increasing in ambient temperature (1 ^{0}C) leads to, resolves the decreasing of output power (1.05) percent.

Figure (5) shows that increasing in ambient temperature leads to increase of heat rate.
Figure (6) shows that increasing in ambient temperature leads to decrease the exhaust flow.
Figure (7) shows that increasing in ambient temperature leads to decrease the Exhaust Flow.
Figure (8) shows that increasing in ambient temperature leads to decrease the thermal efficiency an increase of ambient temperature causes the thermal efficiency to decrease by(1)one percent.

4. CONCLUSIONS

In overall, it can be noted and said that the climatic condition that is peculiar in the site that was not fully addressed at the time of installation of the gas turbine affected the operations and performance of the gas turbine power output.

High ambient temperature is a negative factor and it affects the thermodynamic process of compression, addition of heat and expansion. A part from affecting the processes, the components in which these processes do occur namely the compressor, the combustion chamber and the turbine can also be physically affected

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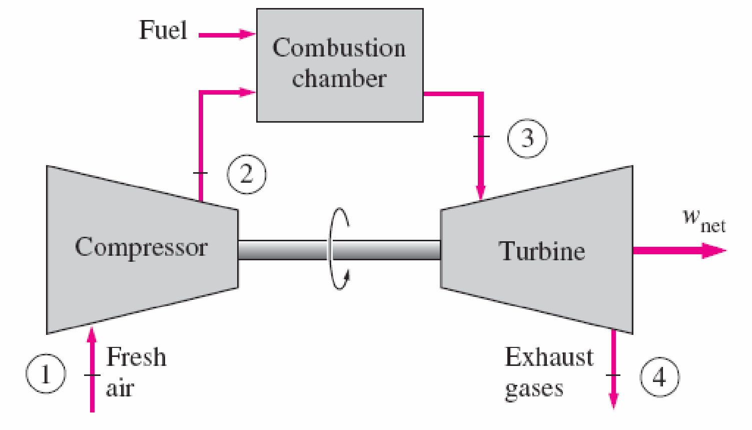

Figure (1): Simple open gas turbine power plant

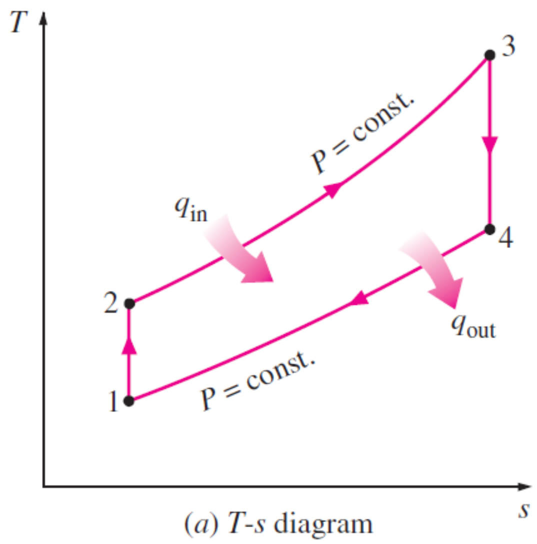

Figure (2): Brayton cycle of simple gas turbine power plant on T-S diagram

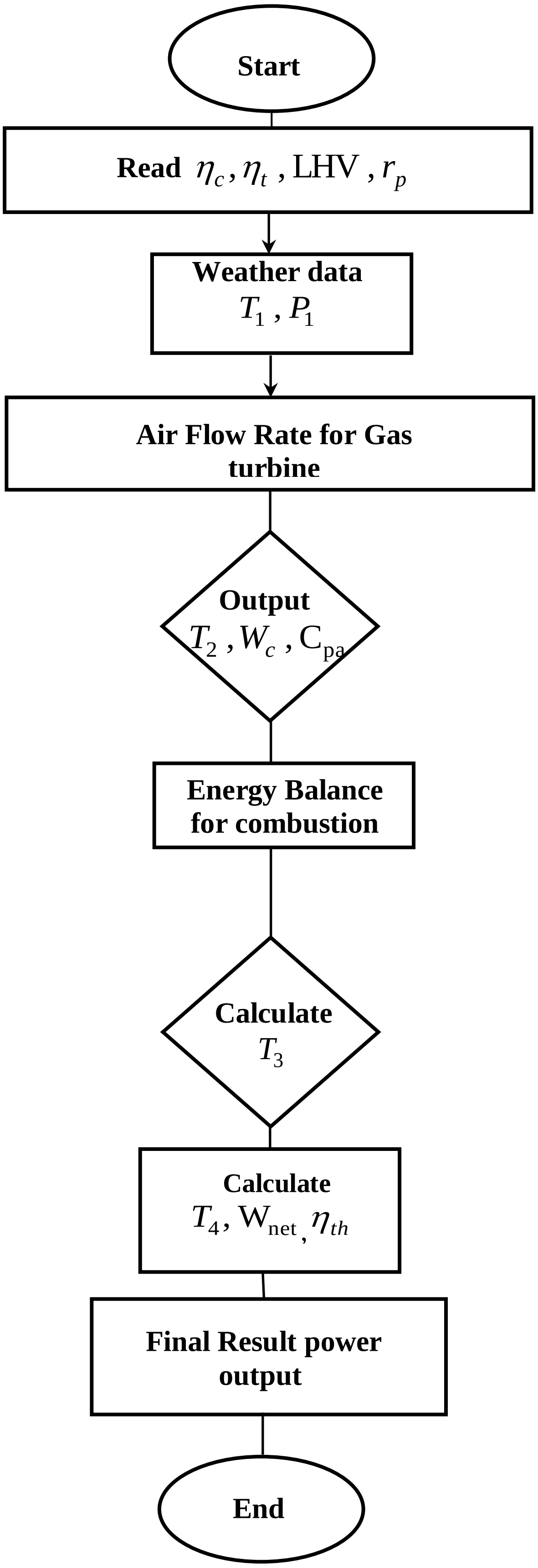

Figure (3): flow chart for performance calculation

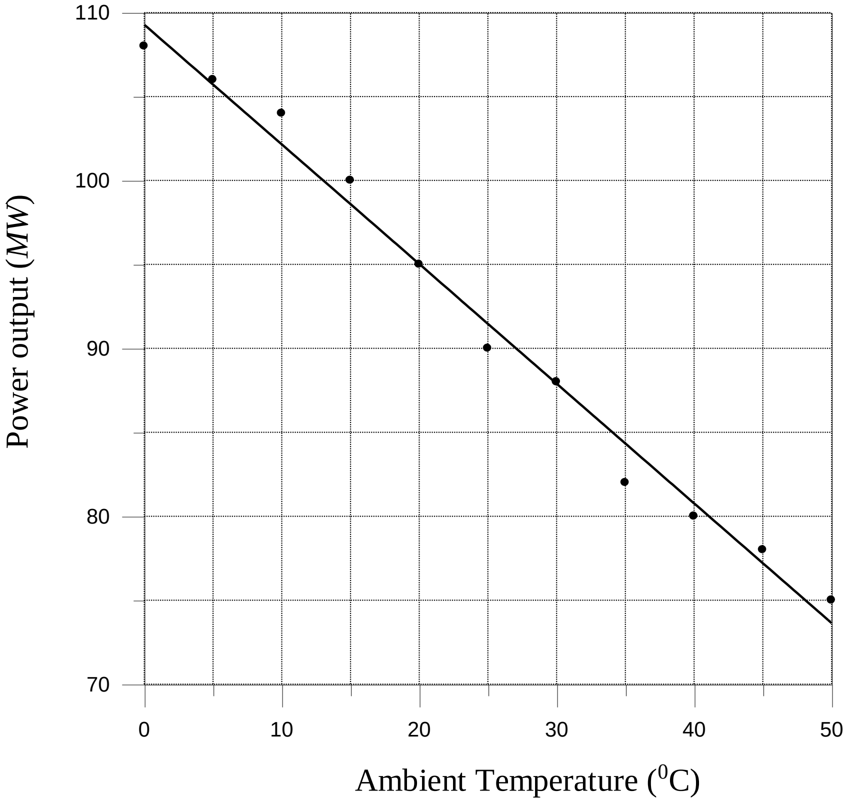

Figure (4): Ambient Temperature versus output Power

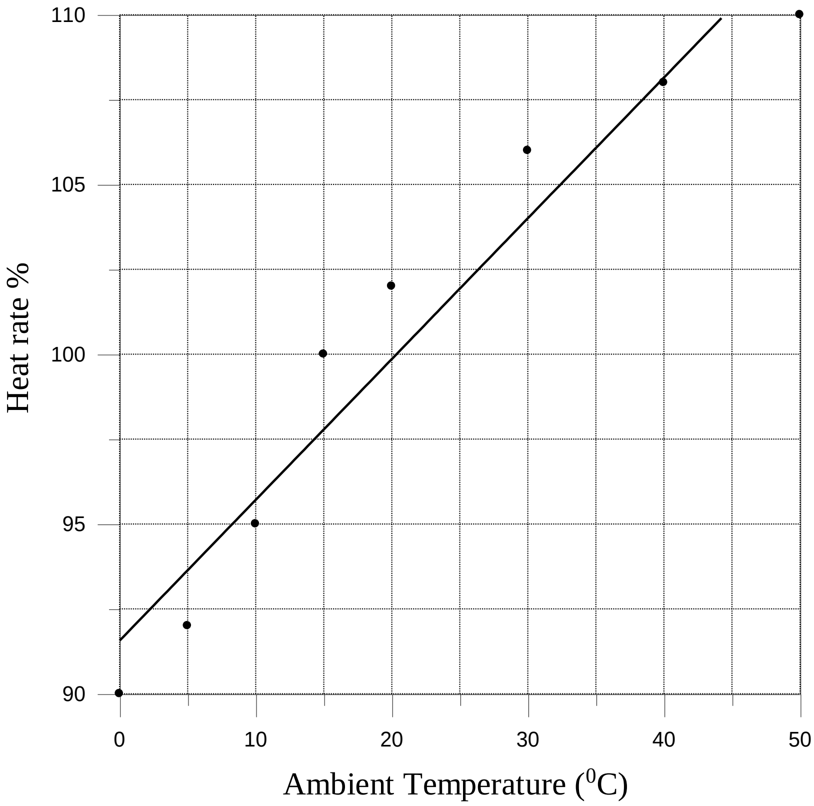

Figure (5) Ambient Temperature versus heat rate

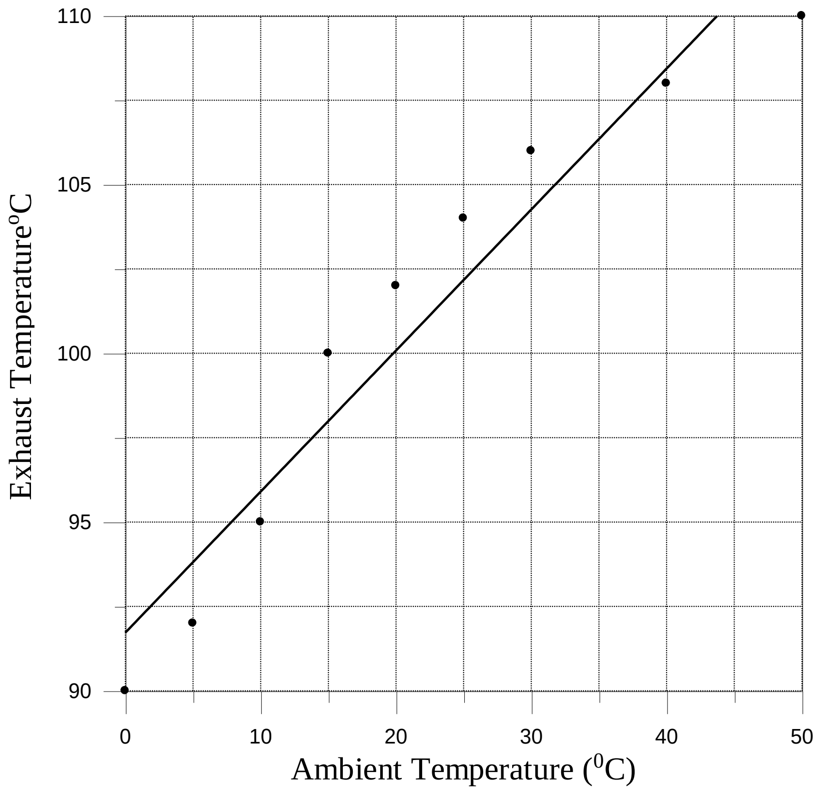

Figure (6): Ambient Temperature versus Exhaust Temperature

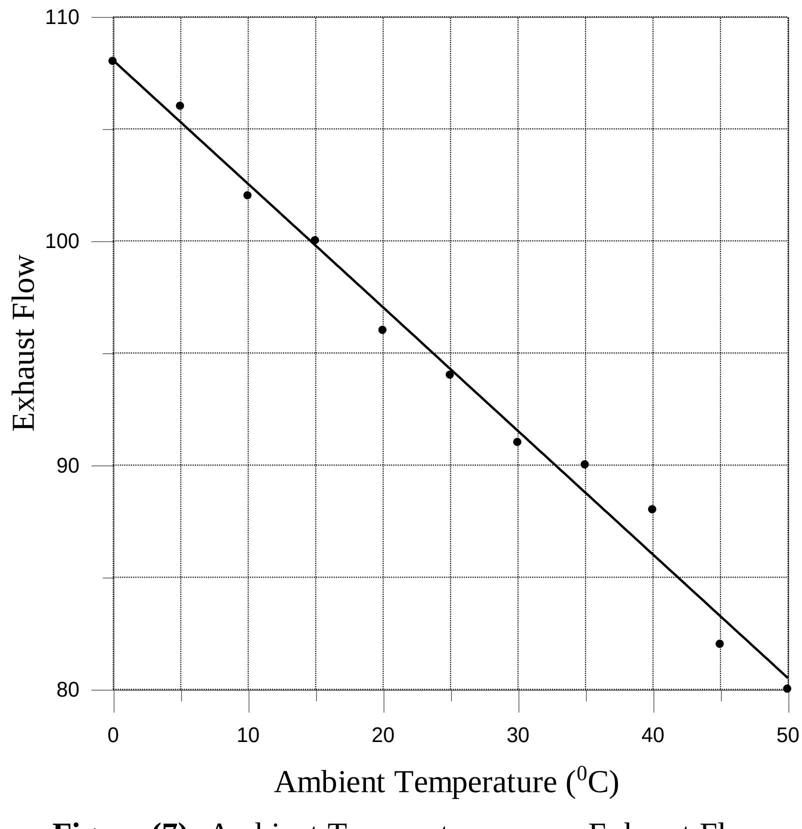

Figure (7): Ambient Temperature versus Exhaust Flow

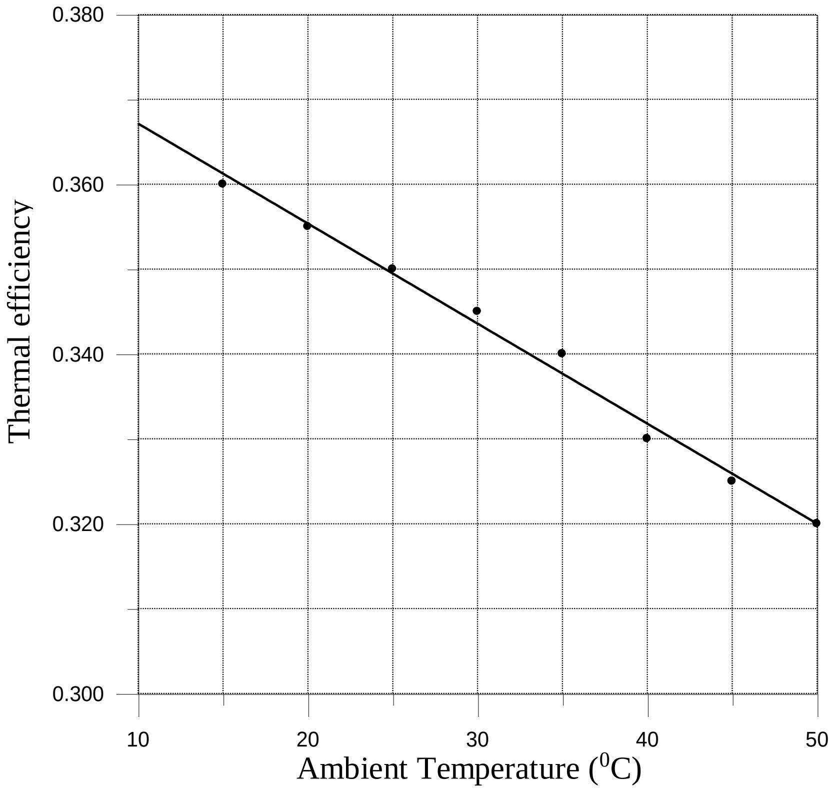

Figure (8): Ambient Temperature versus Thermal efficiency

دراسة تاثير درجة حرارة الهواء الجوي على اداء محطة توليد غازية

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الخلاصة:

في هذا البحث استخدم برنامج حاسوبي لايجاد كفاءة (اداء) محطة توليد كهرباء غازية لمختلف درجات الحرارة للهواء الجوي الداخل الى الضاغطة التي تمثل المرحلة الاولى للمنظومة.وهذا مهم جدا خصوصا في العراق حيث يكون فارق درجات الحرارة للهواء الجوي كبير خلال السنة.لنتائج اظهرت انخفاض واضح في اداء المنظومة بزيادة درجات الحرارة خصوصا في فصل الصيف والتي تمثل مرحلة الذروة للطلب على الطاقة الكهربائية لذلك من المناسب استخدام منظومة تبريد لتبريد الهواء الداخل الى الضاغطة من اجل تحسين الاداء.الدراسة تمت على وحدة توليد بطاقة قصوى (20 MW)، بترتيب محور ,واحد وبدورة بسيطة.