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THERMO-ECONOMIC IMPACT FROM USING EXHAUST GASES HEAT LOST FOR POWERING AN ABSORPTION REFRIGERATION SYSTEM USED FOR INLET AIR COOLING OF COMPRESSOR

Hussam T. Khrebish[1] and Hussien S. Sultan[2]

[1] B.Sc. Mechanical Engineering, College of Engineering, University of Basrah, Basrah – Iraq E-mail: msc.hussam@gmail.com

[2] Ph.D. Mechanical Engineering, College of Engineering, University of Basrah, Basrah – Iraq E-mail: sajadhusseen@gmail.com

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ABSTRACT

The heat lost from gas turbine power plants with exhaust gases represents the most important source for lowering its thermal efficiency. Also, the thermal efficiency of gas turbine can be affected significantly by the ambient surrounding temperature. In Basrah, a lot of gas turbine units have been installed during the last period. In this study, the thermal-economic impact of the heat lost from gas turbine power plant (GTPP) to the atmosphere for different ambient temperature is studied. Heat recovery system is used, the heat recovery system is an absorption refrigeration system used for cooling the air inlet to the gas turbine cycle. For combined system gas turbine-refrigeration cycle, the performance and economic analysis are performed. The results shows that as, the output power and thermal efficiency are decreased by 0.97 MW and 0.0726% respectively for each unit temperature rise of the ambient temperature. The used of the absorption chiller would increase the output power by 23.3%. Also, the thermal efficiency increased by 23.35%.

KEYWORDS: Gas Turbine, Inlet Air Cooling to The compressor and Absorption Refrigeration System.

1. INTRODUCTION

The gas turbine is an internal combustion (IC) engine that uses atmospheric air and combustion gases as a working fluid. The GTPP is used to generate electricity, operate aircraft, trains, and ships and other industrial applications (Mahmood F. and Mahdi D., 2013).

Gas turbine heat engines considered one of represents the most appropriate solutions to the problems of power in Iraq, and especially for hottest months in the year (about eight months in Basrah city from March to October). GTPP has the following characters, low capital cost and short time synchronization, a 30-minutes (Ali Marzouk and Abdalla Hanafi, 2013) (Time to reach basic load from zero speed for gas turbine), for electricity grid is stability, and due to the availability of fuel gas in many countries such as Iraq.

For the aforementioned reasons, many gas turbine have been installed in the last few years. Most of these power plant have been installed in the southern part of Iraq, specifically in Basrah. Al-Basrah contains more than five gas turbine power plants, has been recently established to increase the power especially in summer season. GTPP is affected by the high temperature of the external environment, resulting in low power and efficiency. To increase the power and efficiency of the gas turbine power plant, there are different methods can be used. The most important one is the use of exhaust gases coming out of the gas turbine for powering the absorption cooling system, which improves the conditions of the air inside the gas power compressor and thus increases the power of the gas station.

Al-Najybia gas-turbine power plant is choosing as a case study. The power plant consists of four units with a capacity of 125 MW for each unit. In the present study, all the calculations are performed for one unit only. The thermal impact is studied in terms of energy analysis for Al-Najybia GTPP for different ambient temperature for twelve months. Also, the economic loss a companied with the heat lost from the exhaust gases for different ambient temperature are estimated.

Ana and Claudia, 2012, Sahil et al, 2013, Dinindu R., 2014, Badam et al 2016, Robert et al, 2017, and Saleh et al, 2018 explained the effect of intake air temperature on gas turbine performance and the comparison between the available intake air cooling methods and also, indicated the sub-cooling multistage compressor system coupled with wet cooled condenser and the single-effect LiBr-H2O absorption refrigeration systems show better performance.

2. METHODOLOGY

2.1. Thermodynamics Analysis (Energy Analysis) for Open Gas Turbine Cycle

In this section, the mathematical model for evaluating the performance of Al-Najybia GTPP is reported. Overall system performance is evaluated under different operating conditions. The model gives the ability to evaluate the variation of the power output and the exhaust mass flow rate with ambient temperature. The scheme of the cycle is given in Fig. 1.

Each component is denoted with numbers at the inlet and outlet. The properties of each point in the plant are denoted at the same number as can be seen in Fig. 1.

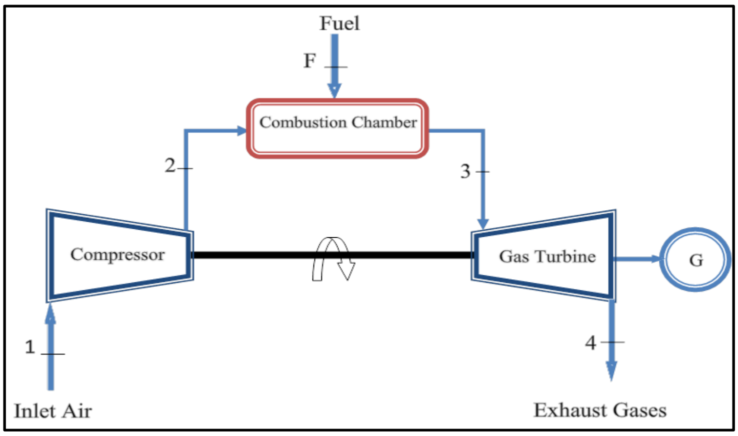

Fig. 1. Open Simple Cycle Gas Turbine Power Plant.

Thermal efficiency and the electric output power of gas turbine units vary according to the ambient conditions (ambient temperature). The amount of these variations importantly affects electricity production and fuel consumption of the power plant. The analysis of each component of the cycle shown in Fig. 1 is given below.

2.1.1. The Air Compressor

The gas turbine is known as a constant volume machine which means that, the total volume of the air inlet to the compressor is constant. This volume is calculated at the ISO conditions of the gas turbine which are P=101.325 bar, T=15 °C, and relative humidity of (60%).

The air mass flow rate inlet to the compressor is given by:

$$\dot{m}_a = \rho_a * v_{a_{rated}} \qquad 1$$

The isentropic efficiency of compressor $\eta_{is,C}$, can be evaluated using the following empirical relation [Rahim et al, 2012]:

$$\eta_{is,C} = \left[1 - \left(0.04 + \frac{(r_p - 1)}{150}\right)\right] \qquad 2$$

The work required for the compressor is given by the relation (Hussien S., 2016):

$$\dot{W}_C = \dot{m}_a C_{P_a}(\acute{T}_2 - T_1) \qquad 3$$

2.1.2. The Combustion Chamber

The fuel is burned with air coming from the compressor in the combustion chamber.

The fuel ratio f is expressed as (Emughiphel N. et al, 2016):

$$f = \frac{\dot{m}_f}{\dot{m}_a} = \frac{C_{P_a} * T_3 - C_{P_a} * \acute{T}_2}{LHV - C_{P_g} * T_3} \qquad 4$$

The specific heat at constant pressure of air is a function of temperature is given by:

$$C_{P_a}(T) = 1.04841 - \frac{3.83719}{10^4}T + \frac{9.45378}{10^7}T^2 - \frac{5.49031}{10^{10}}T^3 + \frac{7.92981}{10^{14}}T^4 \qquad 5$$

Where the unit of temperature is Kelvin.

2.1.3. The Gas Turbine

The combustion chamber exhaust gases, inlet the turbine at high temperature. High-temperature and pressure gases expand in turbines and produce work that converts to electrical energy in the generator.

The gas mass flow rate inlet to the turbine is given by (Hussien S., 2016):

$$\dot{m}_g = \dot{m}_a + \dot{m}_f \qquad 6$$

The isentropic efficiency for gas turbine $\eta_{is,T}$, can be evaluated using the following empirical relation [Rahim et al, 2012]:

$$\eta_{is,T} = \left[1 - \left(0.03 + \frac{(r_p - 1)}{180}\right)\right] \qquad 7$$

The useful work from the gas turbine is given by the relation (Hussien S., 2016):

$$\dot{W}_T = \dot{m}_g C_{P_g}(T_3 - \acute{T}_4) \qquad 8$$

The network (output power) obtained from the gas turbine power plant is given by (Hussien S., 2016):

$$\dot{W}_{net} = \dot{W}_T - \dot{W}_C \qquad 9$$

The heat released from fuel combustion $\dot{Q}_{in}$ is given by:

$$\dot{Q}_{in} = \dot{m}_f * \mathrm{LHV} \qquad 10$$

Thermal efficiency of the gas turbine unit is given by:

$$\eta_{\mathrm{th,GT}} = \frac{\dot{W}_{net,GT}}{\dot{Q}_{in}} \qquad 11$$

2.2. Thermodynamics Analysis of the Gas Turbine Combined with ARS

One of the methods that can be used for recovery the available heat from the exhaust gases is to use the available heat for powering an absorption refrigeration system. The absorption refrigeration system is used for cooling the inlet air to the compressor. This cooling process improves the efficiency of the gas turbine unit especially in the hot regions such as Basrah city. The efficiency of the gas turbine inversely proportional to temperature of the inlet air. From the literature, the efficiency of gas turbine decreased by 18% when the ambient temperature reaches 40 ℃ (Ali Marzouk and Abdalla Hanafi, 2013).

Fig. 2 shows the gas turbine power plant combined with an absorption refrigeration system (single stage Lithium Bromide-Water Absorption chiller).

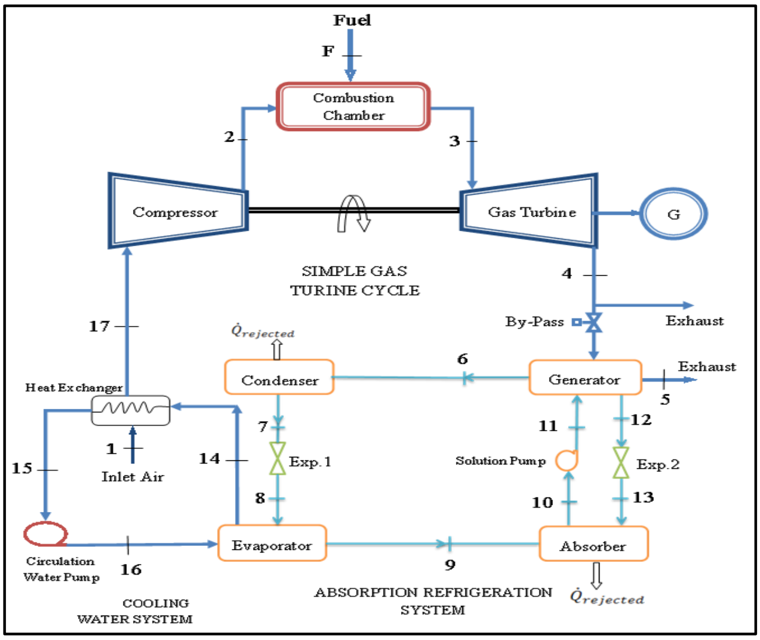

Fig. 2. Gas Turbine Cycle Connected With Absorption Refrigeration System.

The mass balance of the absorption refrigeration system refer to Fig. 2 is given by:

$$\dot{m}_{ws} = \dot{m}_{10} = \dot{m}_{11} \qquad 12$$

$$\dot{m}_{ss} = \dot{m}_{12} = \dot{m}_{13} \qquad 13$$

$$\dot{m}_{ref} = \dot{m}_6 = \dot{m}_7 = \dot{m}_8 = \dot{m}_9 \qquad 14$$

Where:

$\dot{m}_{ws}$, $\dot{m}_{ss}$ and $\dot{m}_{ref}$ refer to weak solution, strong solution and refrigerant mass flow rates respectively.

2.2.4. The First Analysis of Absorption Refrigeration System

Energy Analysis of Evaporator

The cooling load for the evaporator is the heat rate absorbed from the air inlet to the compressor of the gas turbine unit as given below:

$$\dot{Q}_E = \dot{m}_a * C_{Pa} * \Delta T_a \qquad 15$$

Also, the absorbed heat from the refrigerant in the evaporator is given by [Ibrahim D and Mehmet K, 2010]:

$$\dot{Q}_E = \dot{m}_{ref} * (h_9 - h_8) \qquad 16$$

Where:

$$h_8 = h_{sat.liquid} \text{ at } T_C \qquad 17$$

$$h_9 = h_{sat.vapor} \text{ at } T_E \qquad 18$$

The mass flow rates of cooling water in evaporator system is given by:

$$\dot{m}_w = \dot{Q}_E / C_{Pw} * \Delta T_w \qquad 19$$

The evaporator pressure is saturated water vapor pressure at evaporator temperature.

$$P_A = P_E = P_{sat.} \text{ at } T_E \qquad 20$$

Energy Analysis of the Absorber

The mass balance of the absorber is given by:

$$\dot{m}_{10} = \dot{m}_9 + \dot{m}_{13} \qquad 21$$

The Lithium Bromide (LiBr) concentration balance is given by:

$$\dot{m}_{13} * X_{ss} = \dot{m}_{10} * X_{ws} \qquad 22$$

The heat absorbed by the absorber is given by:

$$\dot{Q}_A = \dot{m}_{ref} h_9 + \dot{m}_{ss} h_{13} - \dot{m}_{ws} h_{10} \qquad 23$$

Where:

$$h_{10} = h_{ws} \text{ at } (P_A \; and \; T_A) \qquad 24$$

Energy Analysis of Solution Pump

The energy balance of solution pump is given by:

$$\dot{W}_{pump} = \dot{m}_{ws,10} * v_{ws} * (P_G - P_A) \quad 25$$

Where:

$$P_G = P_C = P_{sat.} \text{ at } T_C \quad 26$$

Energy Analysis of Generator

In the generator, the required heat is supplied from a fraction of the exhaust gases of the simple gas turbine system by using by-pass.

$$\dot{Q}_G = \dot{m}_{g_f} C_{P_g} (\acute{T}_4 - T_i) \quad 27$$

The mass balance of the generator is given by:

$$\dot{m}_{12} = \dot{m}_{11} - \dot{m}_6 \quad 28$$

The lithium bromide (LiBr) concentration balance is given by:

$$\dot{m}_{11} * X_{ws} = \dot{m}_{12} * X_{ss} \quad 29$$

The required heat to operated the generator is given by (Ibrahim D and Mehmet K, 2010):

$$\dot{Q}_G = \dot{m}_{ss} h_{12} + \dot{m}_{ref} h_6 - \dot{m}_{ws} h_{11} \quad 30$$

Where:

$$h_{12} = h_{ss} \text{ at } (X_{ss} \; and \; P_G) \quad 31$$

$$h_6 = h_{ref} \text{ at } (T_G \; and \; P_G) \quad 32$$

The exhaust gases mass flow rate to the generator is given by:

$$\dot{m}_{g_f} = \frac{\dot{Q}_G}{C_{P_g} (\acute{T}_4 - T_i)} \quad 33$$

Energy Analysis of Condenser

In the condenser, the water vapor is condensed by using cooling tower. The rejected heat by the condenser is given by:

$$\dot{Q}_C = \dot{m}_{ref} * (h_6 - h_7) \quad 34$$

Where:

$$h_7 = h_{sat.liquid} \text{ at } T_C \quad 35$$

2.2.5. Performance Properties of the Gas Turbine Cycle with ARS

The output power of the gas turbine cycle with the cooling air system is given by (Ali M and Abdalla H, 2013):

$$\dot{W}_{net.GT\ ,after\ cooling} = (\dot{W}_T - \dot{W}_C) - \dot{W}_{pumps} \quad 36$$

The saving power, the results by cooling the inlet air compressor using ARS is given by:

$$Power\ Saving = \dot{W}_{net.GT\ ,after\ cooling} - \dot{W}_{net,GT,befor\ cooling} \quad 37$$

The coefficient of performance of ARS, can be calculated by:

$$COP = \frac{\dot{Q}_E}{\dot{Q}_G + \dot{W}_{pump}} \quad 38$$

The heat balance of the ARS is given by [Ibrahim D and Mehmet K, 2010]:

The supplied heat rate, $\dot{Q}_{supplied} = \dot{Q}_G + \dot{Q}_E$ 39

The rejected heat rate, $\dot{Q}_{rejected} = \dot{Q}_C + \dot{Q}_A$ 40

2.3. The Economic Gas Turbine Combined with an ARS (Inlet Air Cooling System)

The cost of the electrical power production unit of the gas turbine unit combined with the inlet air cooling system (refrigeration system) is calculated. Also, the cost of the power saving results of increasing the power output from gas turbine due to using the absorption refrigeration system for compressor inlet air cooling is estimated.

The cost for an electrical power production unit (C_e) is given:

$$C_e = \frac{\beta\ C_o}{H} + \frac{f}{\eta_o} + \frac{U}{WH} + V \quad 41$$

Where:

The total efficiency of the plant, $\eta_o = \frac{W}{Q}$ 42

C_o: the cost of the fuel.

β: The commission is based on the capital and depends on discount rate and the life of the station.

W: Plant capacity (kW).

H: Number of actual annual operating hours.

f: Fuel unit price ($/kWh)

Q : The fuel energy consumption (kW)

The cost of maintenance and operation (OM), can be expressed as a sum of fixed operating costs U ($/year), which include (employee wages, insurance, rent, administrative expenses, etc.) and variable operating costs V ($/kWh), which include maintenance fees and spare parts.

Using an absorption refrigeration system for cooling the air inlet to the compressor causes an increase in the power output for gas turbine unit. The economic gain results from the power saving is given below:

$$C_9 = C_{e,GT}\ (\$/MWh) * Power\ Saving \qquad 43$$

3. RESULTS AND DISSCATION

In this section the results of the energy analysis for Al Najybia GTPP will be viewed. The specifications for Al Najybia GTPP are given in Table 1 shown below. The analysis considered the effect of the ambient temperature for Basrah city for twelve months. The goal of the analysis is to explain the effect of exhaust gases mass flow rate on the energy economic efficiency for different ambient temperatures.

In this section, the results of the previous cases mentioned in section two will be explained and discussed.

Table 1. Gas Turbine Unit Design Data.

Item	Rate	Remarks
Gas turbine output	125 MW	At ISO condition
Air inlet temperature	15 ℃	
Relative humidity	60 %	
Average air mass flow rate	407.8 kg/s	
Ambient pressure	1.013 bar	
Exhaust gases temperature	544.5 ℃	
Exhaust gases flow rate	416 kg/s	
Compression ratio	12.5	
Fuel gas mass flow rate	8.2 kg/s	
Efficiency	35 %	

3.1. Effect of Ambient Temperature on the Exhaust Gases Mass Flow Rate

The mass flow rate of the exhaust gases from the gas turbine depends on the mass flow rate of the inlet air to the compressor and the mass flow rate of the fuel added in the combustion chamber. Both the mass flow rate of air and fuel have different values for different values of ambient temperature. In this section, the effect of ambient temperature on the inlet mass flow rate of gases will be explained.

Gas turbine considered a constant volume machine (Ahmed M. et al, 2011) which means that, the volume of air inlet to the compressor is constant for all ambient conditions. So, when the ambient temperature increased the mass of air contained in the inlet volume will be different for different ambient temperature.

The calculations are performed for Al-Najybia GTPP for constant pressure ratio, TIT and exhaust gases temperature. The average ambient temperature for each month is given in Table 2.

Table 2. Average Ambient Temperature for Each Month.

Month	Average Ambient Temperature(℃)
January	20.5
February	20.6
March	27.7
April	34.6
May	42
June	46.2
July	49.6
August	49.3
September	45.9
October	38
November	28.6
December	23.7

For the average ambient temperatures given in Table 2, the variation of the average exhaust gases mass flow rates with ambient temperature are given in Fig. 3 and Fig. 4.

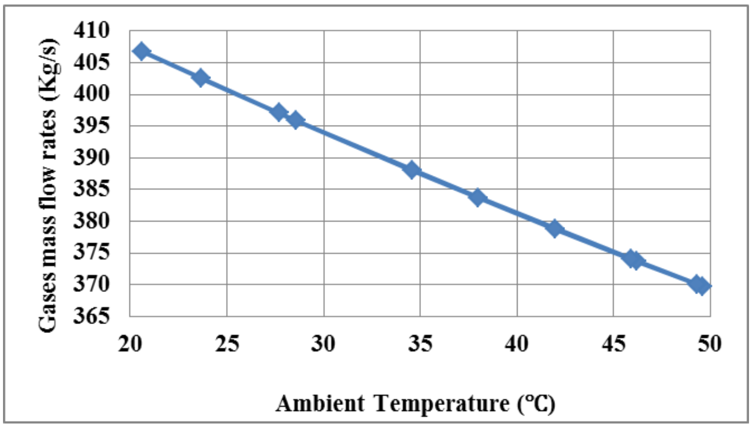

Fig. 3. Variation of Gases Mass Flow Rates with Ambient Temperature.

Fig. 4.Variations of Exhaust Gases Mass Flow Rates For Each Month.

It is clear from Fig. 3 as the ambient temperature increased the gas mass flow rate is decreased, due to the air and fuel mass flow rates are decreased.

So, Fig. 4 shows the variation of exhaust gas mass flow rates for each month. It is clear that, the exhaust gases mass flow rate decreased for hot month and the minimum exhaust gases mass flow rate occurs in July and August months.

3.2. Effect of Ambient Temperature on Network of Gas Turbine Power Plant

The gas turbine output power depends on turbine output work and the compressor input work. Both the turbine and compressor work are changed with the ambient temperature variation.

For the average ambient temperature given in Table 2, the variation of the average net-work is given in Fig. 5.

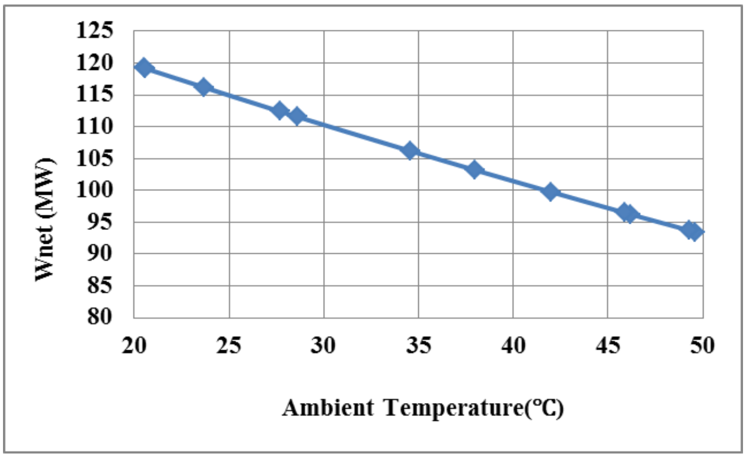

Fig. 5. Variation of Network With Ambient Temperature.

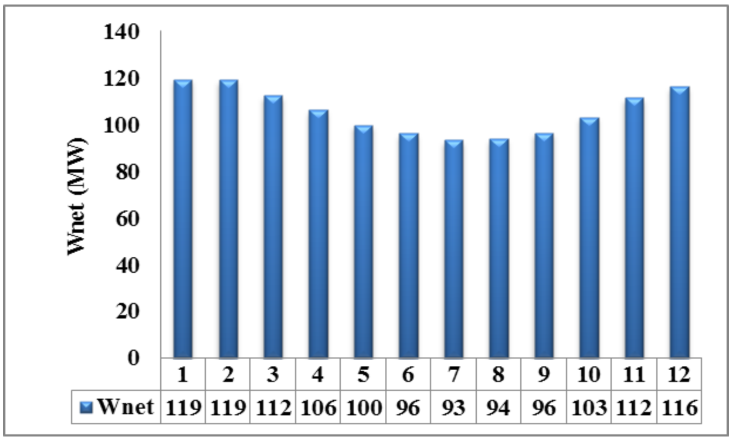

Fig. 6. Variation of Network with Month.

The network decreased with increasing the ambient temperature as shown in Fig. 5 The network decreased by 0.97 MW for each one degree increased in the ambient temperature.

Fig. 6 shows the variation of the net-work for each month. It is clear that, for hot month the network decreased and the minimum network occurs in July and august. The maximum percentage of the reduction is 31.5 MW in the month of July.

3.3. Effect of Ambient Temperature on The Thermal Efficiency of GTPP

The effect of ambient temperature on the thermal efficiency is given in Fig. 7.

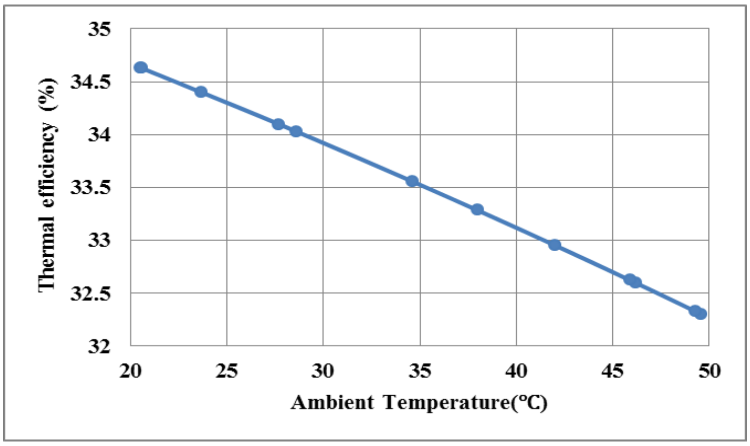

Fig. 7. Variation of Thermal Efficiency with Ambient Temperature.

Fig. 7 shows that the thermal efficiency of gas turbine power plant decreased with increasing the ambient temperature due to the network decreasing which is resulting from the increasing of the compressor work and the decreasing of the inlet air mass flow rate. The thermal efficiency decreased by 0.0726% for each unit temperature rise of the ambient temperature.

3.4. Using the Exhaust Gases for Powering an ARS Used for Compressor Inlet Air Cooling

In this section, the results of the performance analysis for Al-Najybia gas turbine combining with an absorption refrigeration system are viewed. The absorption refrigeration system used to cool the air inlet to the compressor.

The schematic diagram of the combined cycle of the gas turbine and the ARS is shown in Fig. 2.

Firstly, the best operating condition for the absorption refrigeration system is estimated. The analysis for the absorption refrigeration system is done by using EES program. Secondly, the performance of Al-Najybia gas turbine unit with inlet air cooling system is calculated and the power saving due to inlet air cooling are estimated.

Thirdly the economic analysis of the combined gas turbine- refrigeration system will be illustrated.

3.4.1. Estimation the Best Operating Conditions for the ARS

The performance analysis for ARS is performed by using ESS software for different operating conditions. The best operating conditions that gives the maximum COP are estimated.

The best conditions for absorption refrigeration system are given in Table 3.

Table 3. The Optimum Conditions for Absorption Refrigeration System.

Optimum conditions for ARS	
Generator temperature $\boldsymbol{T_G}$	145 ℃
Condenser temperature $\boldsymbol{T_C}$	35 ℃
Evaporator temperature $\boldsymbol{T_E}$	8 ℃
Absorber temperature $\boldsymbol{T_A}$	35 ℃
Condenser pressure $\mathbf{P_C}$	5.627 kPa
Evaporator pressure $\mathbf{P_E}$	1.073 kPa

3.4.2. Analysis of Absorption Refrigeration System when Cooling the Inlet Air to the Compressor Only

The results of performance analysis of absorption refrigeration system when the air inlet to the compressor cooled only are given in Table 4.

Table 4. Performance Analysis Results for ARS.

Component	Value
Q_G , kW	12534
Q_C , kW	10143
Q_E , kW	9147
Q_A , kW	11538
W_P , kW	30.56
COP	0.728
Avg.$Q_{Avail.}$, MW	176.45
%(Q_G/ Avg.$Q_{Avail.}$)	7.1034

Table 4 shows that, the amount of heat required for the generator is less than the available heat that can be recovered from the exhaust gases.

3.4.3. Analysis of ARS when Cooling the Inlet Air to the Compressor and Cooling Load for Power Plant

The results of performance analysis of absorption refrigeration system when the air inlet to the compressor is cooled and also, the air required for conditioning the buildings the power plant. The results of performance analysis are given in Table 5.

Table 5. Performance Analysis Results for ARS.

Component	Value
Q_G , kW	15911
Q_C , kW	12875
Q_E , kW	11611
Q_A , kW	14646
W_P , kW	38.79
COP	0.728
Avg.$Q_{Avail.}$, MW	176.45
%(Q_G/ Avg.$Q_{Avail.}$)	9.0172

Table 5 shows that, the amount of heat required for generator is less than that available heat.

The cooling load required for air conditioning for the buildings of gas turbine power plant is 704 TR = 704*3.5 =2464 KW.

3.5. Al-Najybia Gas Turbine Performance with ARS

The absorption refrigeration system is assumed to cool the air inlet to the compressor by a temperature difference of (25 °C) from the ambient. Since the ambient temperature differs for each month. So, the inlet air temperature also differs for each month. In this section only the results of the five hottest months are considered.

The network of Al-Najybia gas turbine with and without absorption refrigeration system, and the power saving with compressor inlet air cooling are given in Table 6.

It is clear that, using the absorption refrigeration system lead to increase network output due to increasing the mass flow rate of air inlet to the unit.

Also, the power saving decreases with increasing the ambient temperature due to the decrease in the mass flow rate of air inlet to the unit.

The used of the absorption chiller increase the output power by 23.3%.

3.6. The Thermal and Exergy Efficiency of GTPP with ARS

The thermal and exergy Efficiency of GTPP with the absorption refrigeration system for the hottest five months are given in Fig. 8.

Table 6. Performance Analysis Results For GTPP With ARS.

Month	T_1(°C)	T_{17}(°C)	$W_{net.GT}$ (MWh)after cooling	$W_{net.GT}$ (MWh)	Power Saving
May	42	17	122.8	99.745	23.055
June	46.2	21.2	118.688	96.236	22.452
July	49.6	24.6	115.44	93.46	21.98
August	49.3	24.3	115.724	93.7	22.024
September	45.9	20.9	118.978	96.483	22.495

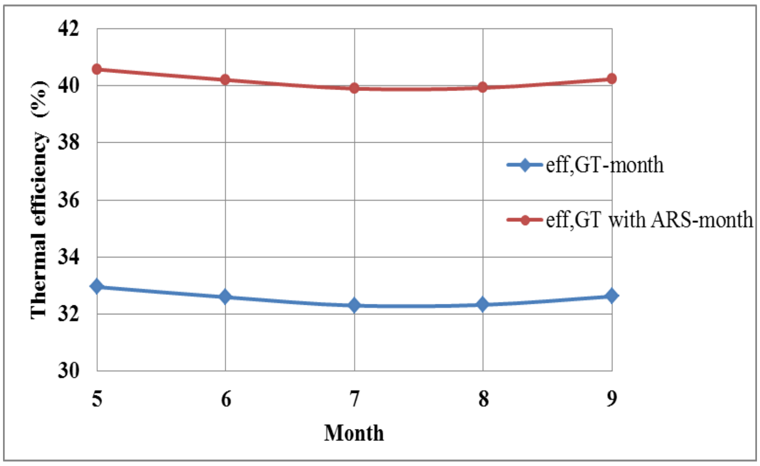

Fig. 8. Variation of Thermal Efficiency per Month.

It is clear from Fig. 8 the thermal and exergy efficiency of GTPP with ARS decreased with increasing the ambient temperature due to decreasing the network. The percentage increase of the thermal efficiency is approximately 23.35%.

3.7. Economic of Gas Turbine with Absorption Refrigeration System

In this section, the economic analysis of the gas turbine unit coupled with absorption refrigeration system will is analyzed for two cases. The first case in which the absorption refrigeration system is used for cooling the air inlet to the compressor only. The second case in which the absorption refrigeration system is used for cooling the air inlet to the compressor and also the cooling load required for air conditioning for comfort for all the plants.

The economic analysis is beginning by calculating the total cost of the absorption refrigeration system. Then the cost of the electrical power production unit for gas turbine combined with the absorption refrigeration system is estimated. Also, the economic gain obtained from coupling the gas turbine with absorption refrigeration system is calculated.

3.7.4. The Total Cost of Absorption Refrigeration System

In this part, the total cost of the ARS is calculated. The total cost of the ARS system represents the summation of the capital cost and the maintenance and operating cost. In these two costs, they depend on the amount of heat to be removed by ARS.

The capital cost of absorption refrigeration system is 500 ($/KW) (Seyed A and Mahbod S, 2014). The operating and maintenance (O&M) costs of absorption refrigeration system is 0.001 ($/TR)=0.000285($/KW).

Table 7 shows the heat load, capital cost and the maintenance and operating cost and the total cost of ARS for the two cases.

Table 7. Cost Analysis for Absorption Refrigeration System.

$\dot{Q}_E(kW)$	IC ($/kW)	O&M($/kW)	Total Cost of ARS ($)	Remark
9147	500	0.000285	4573502.61	Air compressor cooling only
11611	500	0.000285	5805503.31	Air compressor cooling and cooling load for power plant

3.8. The Cost of an Electrical Power Production Unit

The data required for calculating the cost of an electrical power production unit (C_e), for gas turbine power plant with ARS is given in Table 8. The cost of an electrical power is calculated from equation (41).

Table 8. Economic Costs Data For Gas Turbine And Combined Cycle With ARS.

periods	units	G.T &ARS When ACCO	G.T&ARS When ACCLP
C_o	$/kW	578.588	588.444
β	%	6	6
H	h/year	8000	8000
f	$/kWh	0.00338	0.00338
V	$/kWh	0.005	0.005
U	% from C_o	1	1

The calculated cost of an electrical power production unit (C_e), With cooling system for gas turbine power plant is given by Table below:

State	C_e (\$/kWh)	C_e (\$/MWh)
When air compressor cooling only	0.02	20
When air compressor cooling and cooling load for power plant	0.0202	20.2

3.9. Estimation the Economic Gain of Power Saving

The economic gain results from the Incremental production in the electric power output results from using ARS is given in Table 9. The calculations are performed for the five hottest months in the year. The calculations are based on the cost of electric power unit generation for the GTPP which is 19.93 $/MWh.

Table 9. The Economic Gain from Power Saving.

Month	Power saving (MW)	$\dot{C}_9$ (\$/h)
May	23.055	459.48
June	22.452	447.46
July	21.98	438.06
August	22.024	438.93
September	22.495	448.32

Assuming that the cooling system operates 10 hours per day. The cost of power saving per day, month and year are be as given in Table 10.

Table 10. The Cost Of Power Saving Per Day, Month And Year.

Month	Power saving (MW)	$\dot{C}_9$ (\$/day)	$\dot{C}_9$ (\$/month)	$\dot{C}_9$ (\$/year)
May	23.055	4594.9	137845.8	1654150
June	22.452	4474.7	134240.5	1610886
July	21.98	4380.6	131418.4	1577021
August	22.024	4389.4	131681.5	1580178
September	22.495	4483.3	134497.6	1613971

4. CONCLUTION

The main conclusions that can be drawn from this work are summarized as follows:

1- The ambient temperature has an impact on the performance of GTPP in terms of energy, as the output power and efficiency decreasing with the increase of the ambient temperature.

2- The network decreased by 0.97 MW for each one degree increased in the ambient temperature.

3- The thermal efficiency decreased by 0.0726% for each unit temperature rise of the ambient temperature.

4- The performance enhanced when inlet air cooling to compressor of GTPP is used.

5- The used of the absorption refrigeration system would increase the output power by 23.3%.

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