# Exergoeconomic Analysis of a Power Plant in Abu Dhabi (UAE)

Ahmed Nabil Al Ansi[1], Mubarak Salem Ballaith[2], Hassan Ali Al Kaabi[3], Zin Eddine Dadach*[4]

[1,2,3,4]Chemical Engineering Department, Abu Dhabi Men's College, Higher Colleges of Technology, Shakhbout Bin Sultan Street, Abu Dhabi (Abu Dhabi), UAE

*zdadach@hct.ac.ae

***Abstract-*** **Following a previous exergy analysis of a power plant in Abu Dhabi (UAE), a detailed exergoeconomic analysis of the plant based on Specific Exergy Costing (SPECO) method is presented in this investigation. The objective of this applied research is to compare the values of the different exergoeconomic variables of the Open Cycle Gas Turbine (OCGT) calculated during summer atmospheric conditions to the values obtained from the simulation of the plant using design conditions. The results show that summer conditions have increased the total exergy destruction of the power plant and its cost rate respectively by 1.95% and 10%. The negative effects of summer atmospheric conditions on the cost of exergy destruction in the combustion chamber and the compressor are compensated by their positive effects on the turbine. In order to minimize the effects of the summer atmospheric conditions on the performance of the power plant, it is recommended to add a cooling system before the compression of air and a process control system based on the analysis of carbon monoxide, and oxygen of the exhaust gas leaving the combustion chamber.**

***Keywords- Open Cycle Gas Turbine; Exergoeconomic Analysis; Cost of Exergy Destruction; Specific Exergy Costing (SPECO) Method***

## I. INTRODUCTION

The final objective of increasing exergy efficiency of power plants is to reduce the consumption of fuel in order to minimize its environmental impact. In exergoeconomic and exergoenvironmental analyses, exergy destruction costs and environmental impacts are linked to irreversibilities [1-2]. The combination of exergy with costs was first used by Keenan [3] and the concept of exergoeconomics was introduced by Tsatsaronis [4]. The exergoeconomic accounting method is used in the design and operation of gas turbines to calculate the costs of final products as well as the costs of the exergy destroyed within each piece of equipment. Exergoeconomic accounting can be considered an exergy-aided cost reduction approach that uses the exergy costing principle [5]. The standard conditions used for the design of the gas turbine under investigation are 288 K, sea level atmospheric pressure and 60% relative humidity. Its performance could therefore be lower during summer because the atmospheric conditions are different from the ISO requirements. Based on a previous investigation on the exergy analysis of a power plant in Abu Dhabi (UAE), this applied research is also a case study using a methodology described in reference [5]. The final objective of the specific exergy costing (SPECO) method is to detect the equipment of the power plant where it is cost effective to invest in order to reduce the cost of exergy destruction.

## II. BACKGROUND

Exergy destruction (ED) within a component of a power generation plant is the measure of irreversibility that is the source of performance loss. An exergy analysis will determine the magnitude and the source of thermodynamic inefficiencies in a power plant.

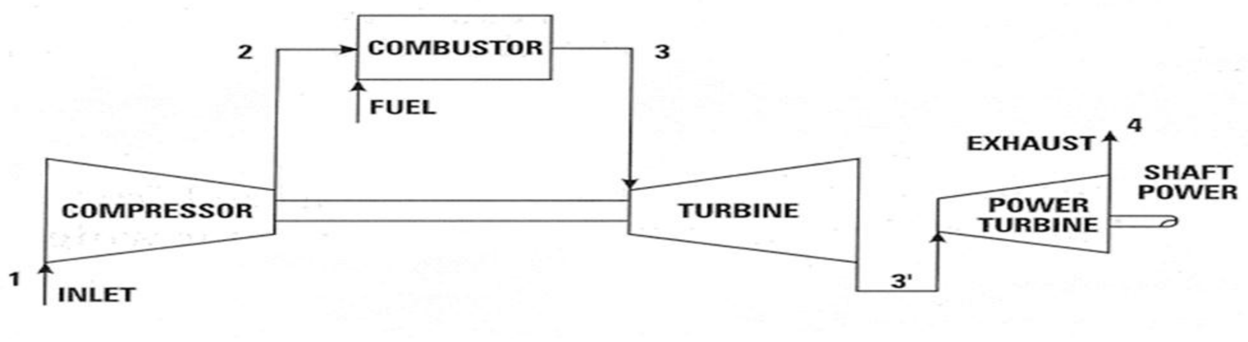


Fig. 1 Schematic Diagram of an Open Cycle Gas Turbine [5]

Based on Figure 1, the exergy destruction (ED) and exergy efficiency (EE) for the three main components of an open cycle gas turbine (OCGT) are defined using the equations [5]:



DOI: 10.5963/IJEE0506003

Compressor

$$(ED)_K = W_K - m_{air}\,(ex_{T2} - ex_{T1}) \quad (1)$$

$$(EE)_K = 1 - \frac{(ED)_K}{W_K} \quad (2)$$

Combustor

$$(ED)_{cc} = m_{air} x\, ex_{T2} + m_{fuel} x\, ex_{fuel} - m_{fg} . ex_{T3} \quad (3)$$

$$(EE)_{cc} = 1 - \frac{(ED)_{cc}}{m_{air} x\, ex_{T2} + m_{fuel} x\, ex_{fuel}} \quad (4)$$

Turbine

$$(ED)_T = m_{fg} x\,(ex_{T3} - ex_{T4}) - W_T \quad (5)$$

$$(EE)_T = 1 - \frac{(ED)_T}{m_{fg} x\,(ex_{T3} - ex_{T4})} \quad (6)$$

For a power generation plant producing electricity using the combustion of fuel, the rate of product exergy of the k$^{th}$ equipment ($\hat{E}_{P,k}$) is the exergy of the desired output resulting from the operation of the component, while the rate of fuel exergy of the same component ($\hat{E}_{F,k}$) is the expense in exergetic resources for the generation of the desired output. The rate of fuel exergy and product exergy of the three main components are defined in Table 1 [5].

TABLE 1 RATE OF FUEL AND PRODUCT EXERGY FOR EACH COMPONENT

| **Equipment** | $\hat{E}_{F,k}$ **(MW)** | $\hat{E}_{P,k}$ $(MW)$ |
|---|---|---|
| **Compressor** | $W_K$ | $m_{air}\,(ex_{T2} - ex_{T1})$ |
| **Combustor** | $m_{air} x\, ex_{T2} + m_{fuel} x\, ex_{fuel}$ | $m_{fg} . ex_{T3}$ |
| **Turbine** | $m_{fg}\, x\,(ex_{T3} - ex_{T4})$ | $W_P + W_K$ |

The rate of exergy destruction within the k$^{th}$ component, $(ED)_k$, is calculated as the difference between its rate of fuel and product exergy [5]:

$$(ED)_k = \hat{E}_{F,k} - \hat{E}_{P,k} \quad (7)$$

And the exergy destruction ratio in each equipment could be written as:

$$Y_{D,k} = \frac{(ED)_k}{\hat{E}_{F,T}} \quad (8)$$

**Economic analysis**

The economic model takes into account the cost of the components, including amortization and maintenance, and the cost of fuel consumption. The first stage of an economic analysis of a power plant is to estimate the purchased equipment cost (PEC). The capital needed to purchase and install equipment is called the fixed capital investment (FCI). A number of methods have been published to estimate the purchase cost of equipment based on design parameters [5-7]. The levelized cost method of Moran [8] is considered in this investigation. The amortization cost (AC) for a component (k) of the power plant depends on the initial cost (IC), the salvage value $S_n$ and the actual cost factor (ACF):

$$(AC)_k = (IC)_k - [S_n x\, ACF\,(i, n)]_k \quad (9)$$

The annualized cost $(\hat{C})_k$ of equipment (k) of the power plant could be estimated using the capital recovery factor (CRF):

$$(\hat{C})_k\,(\$.year^{-1}) = (AC)_k x\, CRF(\,i, n)_k \quad (10)$$

The capital recovery factor (CRF) is a function of the interest (i) and the estimated equipment life (n) [5]:

$$CRF = \frac{ix(1+i)^n}{(1+i)^n - 1} \quad (11)$$

CRF's value of 0.131 is calculated based on an interest rate of 10% and a total operating period of 15 years. Equation (12) could be used to estimate the capital cost rate for the equipment (k) of the plant [5]:

$$\hat{Z}_K = \frac{\hat{C}_k x\, \phi_k}{3600x\, N} \quad (12)$$

$\hat{C}_k$ , $\phi_k$ and N are respectively the annualized cost of the equipment, the maintenance factor and the annual number of operating hours. Considering typical values of the maintenance factor ($\phi_k$ =1.06) and the annual number of operating hours (N=8000)

The cost function of the three main equipment of an open cycle gas turbine could be written as [5]:



DOI: 10.5963/IJEE0506003

Compressor

$$\hat{Z}_K = 71.1x\ m_1 x \frac{1}{(0.9-\eta_K)} xP_r\, xln(P_r)x4.84\ x\ 10^{-9} \quad (13)$$

Where $m_1$ is the mass flowrate of air, $P_r$ is the pressure ratio and $\eta_k$ is the isentropic efficiency of the compressor

Combustor

$$\hat{Z}_{cc} = \left(46.08xm_1 x\left(1+e^{(0.018xT_3-26.4)}\right)x(0.995-(P_3/P_2))^{-1}x\ 4.84\ x\ 10^{-9}\right. \quad (14)$$

Where $T_3$ is the temperature of the exhaust gas and $P_2$ and $P_3$ are respectively the pressures before and after the combustor chamber.

Turbine

$$\hat{Z}_T = \left[479.34xm_{fg}\, x\,(0.92-\eta_{sT})^{-1}xln\left(\frac{P_3}{P_4}\right)x\left(1+e^{(0.036xT_3-54.4)}\right)\right]x4.84\ x\ 10^{-9} \quad (15)$$

Where $m_{fg}$ is the mass flowrate of the flue gas, $P_3$ and $P_4$ are respectively the pressure of the flue gas entering and leaving the turbine and $\eta_{sT}$ is the isentropic efficiency of the turbine.

**Exergoeconomic analysis**

Exergy costing of a power generation plant involves a cost balance for each component separately. In a cost balance around the $k^{th}$ component, the total cost of all exiting streams (e) is equal to the total cost of the entering streams (i) plus the appropriate charges due to capital investment and the expenses for operations and maintenance ($\hat{Z}_k$). Table 2 represents the cost balances and the auxiliary equations of the three main equipment of the power plant:

TABLE 2 COST BALANCES AND AUXILIARY EQUATIONS [5]

| Equipment | **Cost balance** | **Auxiliary equations** |
|---|---|---|
| **Compressor** | $\hat{C}_2 = \hat{C}_1 + \hat{C}_{w,K} + \hat{Z}_K$ (16) | $\hat{C}_1$ =0 (17) ( Assuming no cost for fresh air) |
| **Combustor** | $\hat{C}_3 = \hat{C}_2 + \hat{C}_F + \hat{Z}_{CC}$ (18) | |
| **Turbine** | $\hat{C}_4 + \hat{C}_{w,k} + \hat{C}_p = \hat{C}_3 + \hat{Z}_T$ (19) | $\frac{\hat{C}_{w,k}}{W_K} = \frac{\hat{C}_{W,T}}{W_T}$ (20) and $\frac{\hat{C}_4}{E_4} = \frac{\hat{C}_3}{E_3}$ (21) (Assuming the same unit cost for the energy and the flue gas) |

**Cost of exergy destruction**

Invisible in cost balance equations, the exergy destruction cost for each equipment of the power plant can be estimated by combining the equations related respectively to the exergy destruction (ED) and the cost rate balance. Two approaches are usually used to approximate the average cost associated to the exergy destruction within the equipment (k) of the plant. In the first approach, the product exergy rate ($\hat{E}_{P,k}$) is assumed to be fixed and the unit cost of fuel of the $k^{th}$ component ($c_{F,k}$) is independent of the exergy destruction. In this situation, the cost of exergy destruction represents the cost rate of additional fuel that must be supplied to the component (k) of the power plant to compensate the exergy destruction within the equipment and is defined as [5]:

$$\hat{C}_{D,k} = c_{F,k}\ x\ (ED)_k \quad (22)$$

In the second approach, the fuel exergy rate ($\hat{E}_{F,k}$) is considered constant and the unit cost of product of the $k^{th}$ component ($c_{P,k}$) is independent of the exergy destruction. In this case, the cost of exergy destruction represents the loss of product due to the exergy destruction within the equipment (k) and is defined as [5]:

$$\hat{C}_{D,k} = c_{P,k}\ x\ (ED)_k \quad (23)$$

The first approach is utilized in this investigation. The average unit cost of fuel ($c_{F\,k}$) and product ($c_{P,k}$), the cost rate of exergy destruction ($\dot{C}_{D,k}$), relative cost difference ($r_k$) and exergoeconomic factor ($f_k$) are very important factors for an exergoeconomic analysis of power generation plants [1]. The simplest way to estimate the cost of exergy destruction in a power generation plant is to consider the average cost per exergy unit of the fuel as the cost of exergy destruction unit. The cost rate of fuel and product for the three main components of the plant are defined in Table 3 [5].

TABLE 3 COST RATE OF FUEL AND PRODCUT FOR THE MAIN COMPONENTS OF THE POWER PLANT

| Equipment | Cost rate of fuel $\hat{C}_F$ (\$/hr.) | Cost rate of product $\hat{C}_P$ (\$/hr.) |
|---|---|---|
| Compressor | $\hat{C}_{w,k}$ | $\hat{C}_2 - \hat{C}_1$ |
| Combustor | $\hat{C}_2 + \hat{C}_F$ | $\hat{C}_3$ |



DOI: 10.5963/IJEE0506003

| | | |
|---|---|---|
| Turbine | $\hat{C}_3 - \hat{C}_4$ | $\hat{C}_{W,T}$ |

The average cost of fuel ($c_{F,k}$), the average unit cost of product ($c_{P,k}$) can be estimated [6]:

$$c_{F,k} = \frac{C_{F,k}}{\hat{E}_{F,k}} \quad (24)$$

$$c_{P,k} = \frac{C_{P,k}}{\hat{E}_{P,k}} \quad (25)$$

The relative increase in the average cost per exergy unit between the fuel and the product could be expressed by the relative cost difference ($r_k$) [5]:

$$r_k = \frac{c_{P,k} - c_{F,k}}{c_{F,k}} = \frac{1 - EE_k}{EE_k} + \frac{\hat{Z}_k}{c_{F,k} x \hat{E}_{P,k}} \quad (26)$$

The exergoeconomic factor ($f_k$) is often used to evaluate the importance of the capital investment and operating and maintenance costs (non-exergy related costs) compared to the cost linked to the exergy destruction [6]:

$$f_k = \frac{\hat{Z}_k}{c_{F,k} x[(ED)_k] + \hat{Z}_k} \quad (27)$$

## III. RESULTS OF THE EXERGY ANALYSIS OF THE POWER PLANT

The OCGT under investigation is located in Abu Dhabi (UAE) and produces 160 MW at design conditions. (1) The compressor is an axial compressor with 21 stages and the compression pressure ratio is 13.5. (2) The combustion chamber is equipped in ring with 72 environmental burners. The average temperature and pressure of the fuel gas are respectively 303 K and 2510 kPa. (3) The expansion section is composed of a 5-stage gas turbine and a generator.

### Exergy analysis based on summer's operating conditions

As shown in Table 4, the main objective of the exergy analysis of the power plant was to estimate the values of the exergy destruction and the exergy efficiency of each equipment of the power plant during a typical summer day [P= 100.8 kPa, T= 316 K and absolute humidity = 0.03 kg.m-3]

TABLE 4: RESULTS OF THE EXERGY ANALYSIS AT 316 K, ABSOLUTE HUMIDITY = 0.03 kg.m-3 [9]

| Equipment | Exergy destruction (kW) | ED (%) | $Y_{D\,(\%)}$ | EE |
|---|---|---|---|---|
| Compressor | 17445.31 | 12.4 | 3,71 | 0.916 |
| Combustor | 98155.6 | 70.2 | 20.90 | 0.851 |
| Turbine | 24417.2 | 17.4 | 5.20 | 0.938 |
| Power plant | 140018.1 | 100 | 29.81 | 0.331 |

The corresponding values of the rate at which the fuel is supplied ($\hat{E}_F$) and the product is generated ($\hat{E}_P$) in each equipment are shown in Table 5.

TABLE 5 VALUES OF THE EXERGY OF FUEL AND PRODUCT FOR EACH COMPONENT

| Equipment | $\hat{E}_{F,k}$ (MW) | $\hat{E}_{P,k}$ $(MW)$ |
|---|---|---|
| **Compressor** | $W_K$ = 208.8 | $m_{air}\ (ex_{T2} - ex_{T1})$= 190.84 |
| **Combustor** | $m_{air} x\ ex_{T2} + m_{fuel} x\ ex_{fuel}$ = 657.81 | $m_{fg} . ex_{T3}$ = 559.64 |
| **Turbine** | $m_{fg}\, x\ (ex_{T3} - ex_{T4})$ = 393.08 | $W_P + W_K$ = 380 |

### Exergy analysis of the power plant based on simulation

In the second stage of the investigation, exergy analysis and Aspen Hysys V8.6 with the Soave-Redlich-Kwong (SRK) equation of state were utilized in order to simulate the process under design conditions (T=288K, absolute humidity of 0.008 kg.m$^{-3}$). The values of the exergy of fuel and product for each component are shown in Table 6.

TABLE 6 VALUES OF THE EXERGY OF FUEL AND PRODUCT FOR EACH COMPONENT (DESIGN CONDITIONS)

| Equipment | $\hat{E}_{F,k}$ (MW) | $\hat{E}_{P,k}$ $(MW)$ |
|---|---|---|
| **Compressor** | $W_K$ = 183.8 | $m_{air}\ (ex_{T2} - ex_{T1})$= 166.35 |



DOI: 10.5963/IJEE0506003

| | | |
|---|---|---|
| **Combustor** | $m_{air}\, x\ ex_{T2} + m_{fuel}\, x\ ex_{fuel}$ = 633.3 | $m_{fg} \cdot ex_{T3}$ = 551.1 |
| **Turbine** | $m_{fg}\, x\,(ex_{T3} - ex_{T4})$ = 391.92 | $W_P + W_K$ = 362.8 |

**Validation of the simulation results**

The net output of the power plant under design conditions (T=288K, RH=60%) is 160 MW (Source: Company) and our simulation results indicate that the net power produced at design conditions is 163 MW. The relative shift of 1.9% presents a validation of the simulation.

## IV. RESULTS OF THE THERMOECONOMIC ANALYSIS OF THE POWER PLANT

Using the operating conditions to solve equations (13) to (15), the capital cost rate of the three main components of the plant are respectively: Compressor (216 $/hr.), Combustor (25.4 $/hr.) and turbine (349.8 $/hr.). For a selected cost of natural gas of 2.6 $/GJ [12] , an exergy of natural gas of 48.6 MJ/kg and the flow rate of 9.6 kg/s, the total cost of the fuel is estimated at 4232 $/hr. Solving the linear equations (16) to (21), the cost rate of all the streams can be calculated. The results of the analysis are shown in Table 7.

TABLE 7 COST RATE OF DIFFERENT EQUIPMENT AND STRAMS OF THE PLANT

| Stream | $\hat{C}$ ($/hr.) | $\hat{c}$ ($/GJ) |
|---|---|---|
| $W_K$ | 3120.3 | 4.15 |
| $W_T$ | 5678.7 | 4.15 |
| 1 | 0.0 | 0 |
| 2 | 3336.3 | 4.85 |
| Fuel | 4232 | 2.6 |
| 3 | 7593.7 | 3.77 |
| 4 | 2264.8 | 3.77 |

Finally, equations (24) to (27) are utilized to estimate the exergoeconomic parameters of the different equipment of the open cycle gas turbine for design conditions and during summer conditions (Tables 8-9).

TABLE 8 EXERGOECONOMOIC PARAMETERES FOR EACH EQUIPMENT FOR DESIGN CONDITIONS

| Equipment | EE (%) | ED (MW) | $Y_D$ (%) | $\hat{Z}_K$ $/hr. | $c_{F,k}$ $/GJ | $c_{P,k}$ $/GJ | $\hat{C}_{D,k}$ ($/hr.) | $\hat{C}_{D,k} + \hat{Z}_k$ ($/hr.) | $r_k$ (%) | $f_k$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Compressor | 0.916 | 15.45 | 3.74 | 216.0 | 4.24 | 4.85 | 235.83 | 451.82 | 14.8 | 47.8 |
| Combustor | 0.872 | 82.2 | 17.61 | 25.4 | 3.18 | 3.67 | 941.02 | 966.42 | 15.4 | 2.70 |
| Turbine | 0.896 | 29.12 | 6.24 | 349.8 | 3.68 | 4.24 | 385.78 | 735.58 | 15.2 | 47.54 |

TABLE 9 EXERGOECONOMIC PARAMETERS FOR EACH EQUIPMENT DURING SUMMER CONDITIONS

| Equipment | EE (%) | ED (MW) | $Y_D$ (%) | $\hat{Z}_K$ $/hr. | $c_{F,k}$ $/GJ | $c_{P,k}$ $/GJ | $\hat{C}_{D,k}$ ($/hr.) | $\hat{C}_{D,k} + \hat{Z}_k$ ($/hr.) | $r_k$ (%) | $f_k$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Compressor | 0.916 | 17.96 | 3.85 | 216.0 | 4.15 | 4.85 | 260.6 | 476.6 | 16.9 | 45.3 |
| Combustor | 0.851 | 98.17 | 21.04 | 25.4 | 3.19 | 3.77 | 1127.2 | 1152.6 | 18.2 | 2.2 |
| Turbine | 0.938 | 13.08 | 2.80 | 349.8 | 3.76 | 4.15 | 330.5 | 680.3 | 10.4 | 51.4 |

## V. ANALYSIS OF THE RESULTS

According to the literature [6, 10, 11], the components having the highest value of the sum ($\hat{C}_{D,k} + \hat{Z}_k$) are the most important components from the exergoeconomic viewpoint. The value of the relative cost difference (r) for a component shows the degree to which it contributes to increasing the final cost of the product based on the input of the component. A component having a lower value of the exergoeconomic factor (f) means that the greater part of the product cost is due to exergy destruction and loss.

**Combustor**

For the summer atmospheric conditions, the combustor has the highest value of the exergy destruction of 98.17 MW and



DOI: 10.5963/IJEE0506003

the highest value of the sum ($\hat{C}_{D,k} + \hat{Z}_k$=1152.6 \$/hr.). The combustor also has the highest contribution to the cost of the final product (r=18.2) and the lowest contribution of the capital investment (fk= 2.2). From the design conditions, the cost rate of exergy destruction increased by 19.8%. and the relative cost difference increased by 18.2 %. On the other hand, summer atmospheric conditions decreased the exergoeconomic factor by 18.5%. The analysis of these variables indicate that the high cost of the product is mainly due to the cost of exergy destruction within the combustor. This situation becomes more pronounced during summer conditions. The irreversibilities that cause large exergy destruction could be linked to the operating conditions (pressure, temperature flow, composition) of the reactants (fuel +air) at the burners. For an optimum auto-ignition, flame temperature, emissions and stability, it is critical to successfully obtaining a fuel stream (fuel +air) conditions that meet the original equipment manufacturer (OEM) specifications. Otherwise, it will result a high degree of irreversibility and a lower efficiency of the combustion process. Another strategy to reduce the exergy destruction in the combustor is to replace the actual feedforward (ratio) control system by a feedback control system based on a continuous measurements of both O2 and CO leaving the combustor. The new control process could help obtain a 'stoichiometric' mixture for significant energy savings by minimizing excess air.

**Turbine**

For the summer atmospheric conditions, the turbine has the lowest exergy destruction of 13.08 MW and the second highest value of the sum ($\hat{C}_{D,k} + \hat{Z}_k$= 680.3 \$/hr.). The turbine also has the lowest contribution to the cost of the final product (r=10.4) and the highest contribution of the capital investment (fk= 51.4). The summer conditions decreased the cost of exergy destruction of the turbine by 14.3 %. and its contribution to the cost of the final product (r) by 32%. The exergoeconomic factor increased only by 8%. Since the turbine has the highest capital cost rate, the large decrease of its exergy destruction (55%) during summer conditions did not have a significant impact on the value of the exergoeconomic factor. The exergy loss due to the high temperature of the exhaust gas (700 K) leaving the turbine could be minimized by investing in a heat recovery steam generator (HRSG) system in order to increase the net power output of the plant.

**Compressor**

For the summer atmospheric conditions, the compressor has the second highest exergy destruction of 17.96 MW and the lowest value of the sum ($\hat{C}_{D,k} + \hat{Z}_k$= 476.6 \$/hr.). The compressor also has the second highest contribution to the cost of the final product (r=16.9) and the second highest contribution of the capital investment (fk= 45.3). The summer conditions increased the cost rate of exergy destruction and the relative cost factor respectively by 10.5% and 14.2%. On the other hand, the exergoeconomic factor decreased by 5.2%. These findings are in concordance with the increase of the exergy destruction of 16.2% during summer conditions. Previous results show that temperature has more negative effects than the absolute humidity on the power plant. A thermo-economic optimization study is needed in order to select between the different cooling systems (ex: fogging cooling) to decrease the negative effects of the high temperatures on the performance of the compressor.

## VI. CONCLUSION

The effects of summer conditions on the exergy destruction within the three main components of the open cycle gas turbine and their exergy efficiencies were estimated in a previous investigation and summarized in this paper. The objective of this investigation is to study the effects of summer atmospheric conditions on the different exergoeconomic variables of the main equipment of the power plant by conducting an exergoeconomic analysis. Summer atmospheric conditions increased the total exergy destruction of the power plant and its cost rate respectively by 1.95% and 10%. The increase of the cost of exergy destruction within the combustion chamber and the compressor (respectively 19.8% and 10.5%) are compensated by a decrease of 14.3% of the cost of exergy destruction within the turbine. This study shows that the effects of increasing ambient temperature on the combustion chamber attracts the maximum cost in terms of exergy destruction and, thus, constitutes the prime target for capital investment. The effects of irreversibilities within the combustion chamber could be minimized by selecting the adequate fuel to meet the requirements of the combustion and investing in a process control system based on the measurements of the concentration of oxygen and carbon monoxide in the exhaust gas. The cost of exergy destruction in the compressor could be lowered by investing in a system for cooling ambient air before compression. The exergy loss due to the high temperature of the exhaust gas could be minimized by adding a heat recovery steam generator (HRSG) system at the hot stream leaving the turbine.

ACKNOWLEDGMENT

The authors wish to thank Higher Colleges of Technology, UAE for supporting this research work

REFERENCES

[1] Meyer L., Tsatsaronis G., Bushgeister J. and Schebek L., "Exergoenvironmental analysis for evaluation of the environmental impact of energy conversion systems", *Energy - The International Journal* , vol. 34, pp. 75 - 89, 2009.

[2] Petrakopoulou F., Tsatsaronis G., Boyano A. and Morosuk T. "Exergoeconomic and exergoenvironmental evaluation of power plants including CO2 capture, carbon capture & storage" *Special Issue of Chemical Engineering Research and Design*, In press, DOI:



DOI: 10.5963/IJEE0506003

10.1016/j.cherd.2010.08.001.

[3] Keenan, J. H. “A steam chart for second law analysis”, *Trans. ASME*, vol. 54 (3), pp. 195–204, 1932.

[4] Tsatsaronis G., Combination of exergetic and economic analysis in energy conversion processes, in: Energy Economics and Management in Industry (Reis, A., Smith, I., Peube, J. L., Stephan, K., Eds.), Pergamon Press, Oxford, pp. 151 - 157

[5] Bejan A., Tsatsaronis G., Moran M: Thermal Design and Optimization, J. Wiley & Sons Edition. 1996

[6] Cihan A. , Hacıhafızoglu O., Kahveci K., “Energy–exergy analysis and modernization suggestions for a combined cycle power plant”, *International Journal of Energy Research*, vol. 30 (2), pp: 115–126, 2006

[7] Roosen P., Uhlenbruck S., Lucas K., “Pareto optimization of a combined cycle power system as a decision support tool for trading investment vs. operating costs”, *International, Journal of Thermal Sciences*, vol. 42 (6), pp. 553–560, 2003.

[8] Moran J., “Availability Analysis: A Guide to Efficient Energy Use”, *Prentice-Hall*, pp. 199–215, 1982.

[9] Alhosani O., Alhosani, Dadach Z., “Exergy analysis of a power plant in Abu Dhabi (UAE)”, *International Journal of Energy Engineering*, vol. 5(3), pp. 43-56, 2015.

[10] Lazzaretto, A., Tsatsaronis, G., “On the calculation of efficiencies and costs in thermal systems”, *Proceedings of the ASME Advanced Energy Systems Division*, AES, vol.39, 1999.

[11] Karthikeyan R., Hussain M. A., Reddy B. V., Nag P. K., “Performance simulation of heat recovery steam generators in a cogeneration system”. *International Journal of Energy Research*, vol. 22, pp. 399-410, 1998.

[12] Amin A. Z. and Al Zeyoudi, “Renewable energy prospects for the United Arab Emirates”, *Masdar Institute*, April, 2015.


**Ahmed Nabil Al-Ansi** is a senior chemical engineering student at HCT-ADMC with a GPA 3.77. He is a member of the American Institute of Chemical Engineers and a member of carbon ambassador team done by the ministry of foreign affairs and a part of UAE National Green Growth Strategy and Green Agenda research program at Masdar institute. My motivation line is "nothing is impossible or hard if you kept trying, confidence and knowledge is your boat in the journey of life”.

**Mubarak Salem Ballaith** obtained a scholarship from ADNOC group to pursue his undergraduate studies at the chemical engineering department of HCT-ADMC. He is a member of the American Institute of Chemical engineers. He obtained an Internet and Computing core certification (ICDL) from the Institute of Oscars in Abu Dhabi.

**Hassan Ali Alkaabi** is sponsored student by ADNOC group. He is a senior student at the Chemical Engineering department of HCT-ADMC. He is an active member of the student’s chapter of the American Institute of Chemical engineers.



DOI: 10.5963/IJEE0506003

**Zin Eddine Dadach** obtained his Bachelor's degree in Refining and Petro-chemistry from the Algerian Institute of Petroleum in 1980. He received his Master's degree in Chemical Engineering from Stevens Institute of technology (Hoboken, N.J.; USA) in 1984, and his Ph.D. degree in Chemical Engineering from Laval University (Quebec, Canada) in 1994. He worked in an organic materials department at the Osaka National Research Institute (Osaka, Japan) for two years. His scientific research activities include $CO_2$ and $H_2S$ absorption by amines, biomass conversion for the production of fuels and Monte Carlo simulation of stochastic processes. Since he joined the Higher Colleges of Technology (Abu Dhabi, UAE) in 2005, Dr. Dadach has developed active learning strategies to enhance the motivation of students. He supervised a number of student-based applied research (S-BAR) projects including Carbon Capture and Storage strategies, Process Simulation, and Exergy & Exergoeconomic Analysis of power generation plants.



DOI: 10.5963/IJEE0506003