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ENHANCEMENT OF GAS TURBINE PERFORMANCE BY USING FOGGING SYSTEM

M. M. Ammar[a], M. S. Hassan[b] and Mohamed R. O. Ali[b]

[a]Upper Egypt Electricity Production Company
750 MW Korymat Power Plant, EGYPT
[b]Mechanical Power Engineering & Energy Department, Faculty of Engineering,
Minia University, Minia, Egypt

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A B S T R A C T

This paper examines the impact of the fogging system on the gas turbine's performance in terms of output power, compressor work, electrical cycle efficiency, and specific fuel consumption. This was accomplished by analyzing the actual data from the BeniSuef Governorate-based Siemens (V94.3A2) Power Station with a design capacity of 264 Megawatts. The cooling degree hours gave an idea of the potential for using a fogger and an evaporative cooler to cool the gas turbine air in this region. The results showed that gas turbine can operate 13 hours in case of base temperature 20 C with 7848-degree hours in July. Through the recorded values, the results of the analysis showed that operating the fogger during the peak hours of high temperature in summer gives a power of 16 megawatts higher than the power just before operating the fogger. The electrical efficiency increased by 3 %. When the fogger is turned on at air temperature of 38 degrees Celsius, the specific fuel consumption decreases by 1.9%, and when the compressor inlet temperature drops from 30 degrees Celsius to 20 degrees Celsius, the exit temperature from the compressor decreases from 437 degrees Celsius to 417 degrees Celsius, which is a decrease of 4.6%

1. introduction

Gas turbine power plants are widely used to produce power in the world because of their low cost, speed of installation, and rapid response to electricity changes in the electrical network. But the electric power production significantly decreases with the increase of inlet air temperature during summer hot days due to the decrease of density at the same volumetric flow rate. Therefore, gas turbine performance is greatly affected by ambient conditions at the installation site. Flexible solutions are required to enable the usage of gas turbine power plants in summer months [1].

There are different methods that can be used to increase gas turbine capacity such as High-pressure fogging, Absorption chiller cooling, Wetted media evaporative cooling and Thermal energy storage. These methods have undergone much research, and they are now being used on gas turbines all around the world, and the focus of this study is decreasing compressor inlet temperature by High-pressure fogging.

1.1. Wetted media evaporative cooling

wet objective evaporative cooling transfers water through a medium while also moving air through it, it works best in hot, dry situations. The latent heat of water vaporization as a result causes the air to cool from the dry-bulb temperature to the wet-bulb temperature. It is Positives include speedy delivery and installation, low running costs, minimal power usage, and a very low unit capital cost. There are several significant downsides, such as restricted capacity improvement, high purified water consumption, high maintenance expenses related to scaling and water treatment, and limited power gain because of the ambient wet-bulb limitation on incoming air temperature. [1]

The media evaporative cooling system used in the gas turbines of the Fars (Iran) combined cycle power plant was simulated and evaluated by R. Hosseini et al. [2]. The production increased by 11 MW with a temperature drop of 19 ^{0} C, which was achieved at a 38 ^{0} C ambient temperature and an 8% relative humidity. The annual power gain was 5280 MWh, and the payback period at the current prices was four years.

The amount of water required for evaporative cooling in a gas turbine is dependent on the level of cooling required, the environment, and the turbine mass-flow rate, according to Meher-Homji and T.R. Mee [3]. They offered rough estimates of water consumption in their analysis as a function of mass flow rates and degrees of cooling; every degree of cooling takes approximately 300 l/h for every 200 kg/s of mass flow rate.

A GE Frame 6B gas turbine operating at a nominal power output of 40 MW at base load was evaluated thermodynamically by B. Dawoud et al. [4]at an ambient summer temperature of 48.8 ^{o} C. Evaporative cooling and fogging produced gains of 9.4% and 11%, respectively. The 40 MW gas turbine, however, required 12 655 tons of evaporative water and 14 085 tons of fogging water per year.

The usage of an indirect evaporative cooler to increase the power output of a simple cycle gas turbine with a rated efficiency of 27.06 percent was evaluated by R. Hariri and Aghanajafi. [5] using a mathematical model. They demonstrated that the indirect evaporative cooler may cause the turbine under investigation's efficiency to drop to 26.32 percent because the increase in fuel consumption.

1.2. Absorption chiller cooling

In a double effect lithium bromide absorption chiller, heat is recovered from turbine exhaust gases and used by the absorption chiller chilling to create cooled water. A heat exchanger is used to transmit cooled water in order to reduce the temperature of the

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surrounding air. It performs better than evaporative or fogging and is not impacted by the air's surrounding wet bulb temperature. High O&M costs, high capital expenditures, and a complicated system that needs expertise to operate, maintain, and repair are some of its downsides. Not suitable for open-cycle turbines, requires more heat rejection (and cooling tower water) than other systems, and takes longer to ship and install. [1]

S. Karellas et al. [6] developed a computer simulation of a combined cycle plant with a simple cycle gas turbine. In order to show how combining evaporative media with absorption chillers could lead to increases of up to 20%, they examined how ambient air temperatures, which are normally between 40 and 45 ^{0} C in Southern Europe, affect production and efficiency. In spite of the ambient air conditions, the suggested absorption system has the benefit of being able to continuously increase plant output and cool intake air to a predetermined constant temperature.

Iran has more than 170 gas turbine units with a combined capacity of 9500 MW, however the summer's heat results in 1900 MW losses, according to M. Ameri and S.H. Hejazi. [7].They conducted an economic analysis of a gas turbine intake air-cooling system in the Iranian Chabahar power facility. The system presented used a steam-absorption chiller, which increased output power by 11.3%. The additional 14 000 MWh of yearly electricity generation increased revenue by 23.4%, with a payback period of 4.2 years, according to economic calculations.

J.N. Al-Bortmany [8]. described aqua-ammonia absorption chillers that are heated by gas-turbine exhaust gases. Input air for two gas turbines in Oman was cooled to 7 ^{0} C, which resulted in power improvements of 20 and 14%. P. Namprakai et al. [9]. evaluate possibilities for expanding the capacity of an existing combined cycle power plant in Bangkok, Thailand. To reduce the temperature of the ambient gas turbine inlet air to 15 ^{0} C, a steam-absorption chiller is advised. 10.6% is the expected power gain, while the payback time is 3.8 years.

1.3. High-pressure fogging

Demineralized water droplets with a diameter of 5 to 20 microns are sprayed into air intake ducts at pressures between 150 and 200 bar when high-pressure fogging is utilized [1]. The fog droplets evaporate, producing 100% relative humidity, and the air is cooled to the wet-bulb temperature, which is the lowest temperature that can be produced without refrigeration. It is possible to utilize excessive fogging to cause the droplets in the gas turbine compressor to evaporate, which will reduce compressor work and boost turbine power. Technically, fog droplets are kept in the air by Brownian motion and have a diameter of less than 40 microns. It has minimal initial costs, reduces excessive compressor fogging, which reduces compressor work and increases turbine output, uses low specific power, requires little annual maintenance, and is easy to install and distribute. One of its shortcomings is the restricted power increase caused by the ambient wet-bulb constraint on incoming air temperature.

Bhargava and Meher-Homji [10] did a complete parametric research of intake high-pressure fogging in the context of gas turbine design parameters that also addressed factors like the position of nozzles and water quality. Mee III and Meher-Homji [3]. talked on upkeep and operation. Each year, the fog system will require 15-20 hours of maintenance. They recommend positioning the high-pressure fogging nozzles downstream from the air filter if intercooling is required and upstream from the silencers if evaporative cooling is the primary purpose of the fogging in order to give the fog droplets more time to evaporate. They also recommend installing drainage systems for duct and silencer floors, sub-micron filters for water treatment facilities, and water meters to limit overuse of water. This is due to the possibility of silica, which can still cause fouling, in demineralized water.

H. Perez-Blanco et al. [12] evaluated the continuous cooling approach, which uses water injection rates from 2 to 10% of the air mass flow as compared to the conventional intake cooling rate of 1-2%. J.H. Horlock [13] and T. McKay et al. [14] arrived at the same conclusions: Compressor modification may be required since the residence time in the compressor is so brief, on the order of a few hundredths of a second, for the evaporation process to efficiently provide cooling and maintain pressure.

In their study of direct water injection into the compressor, I. Takehara et al. [15] used modelling of a 150 MW turbine with a 14.5:1 pressure ratio to show how direct spray intercooling may boost turbine production by 23 percent with a spray rate of 2.3 percent. H.B. Urbach et al. [16] boosted the power output of an LM-2500 engine by 34% employing a 24 g/m spray rate into the compressor inlet. According to Jonsson and Yan [17] the high fogging Intercooling methods are still at the experimental stage.

2. combined cycle power system description

750 MW combined cycle power station consists of 2*264 MW gas turbine units and a 250 MW steam turbine manufactured by Siemens (V94.3A2) and was built and placed into operation in 2008. The operating fuels of the units are (i) natural gas as the main fuel, which is the specification referred to in Table 2, and (ii) as a secondary fuel, liquid fuel. Table (1) give the design data of Siemens (V94.3A2) gas turbine at inlet standard condition at BeniSuef if the ambient temperature was 15 ºC and the relative humidity 60%

Table 1: Gas turbine design data at (iso) condition

Item	Rate
Gas turbine output, MW	264.344
Air inlet temperature (ISO), °C	15
Relative humidity, %	60
Average air mass flow rate, kg/s	652.71
Ambient pressure, bar	1.013
Exhaust gases temperature, °C	579.8
Exhaust gases flow rate, kg/s	667.3
Heat rate, kJ/kWh	9435.4
Gas lower heating value, kJ/kg	47040
Compression ratio	17.2
Inlet temperature to turbine, °C	1230
Fuel gas mass flow rate, kg/s	14.59
Efficiency, %	38.5

2.1. Natural gas specification.

The fuel used for operating the gas turbine units is natural gas. Its specification is shown in Table 2. The amount of natural gas that burns in the gas turbine combustion chamber is a function of the supply pressure of the gas, the lift of the natural gas control valves, and the combustion chamber pressure. Natural gas pressure is measured upstream of the natural gas emergency stop valve by pressure transducers and downstream of the natural gas emergency stop valve by pressure transducer also. To ensure reliable operation of the gas turbine in all operating modes (diffusion and premix), the natural gas pressure is checked for violation of prescribed maximum and minimum limits. Actions appropriate to the respective operating mode are initiated if these limits are violated, the pressure drop across the combustion chamber is about 100 mbar

Table 2: Natural gas composition (mole fraction)

CH_4	C_2H_6	C_3H_8	C_4H_{10}	CO_2	N_2
88.68%	6.23%	0.68%	0.09%	3.38%	0.94%

2.2. fogging system description

Direct input fogging is a cooling method that uses special atomizing nozzles that operate at high pressure to transform demineralized water into a fog. When the fog evaporates in the gas turbine's air input duct, it offers cooling. This technology achieves 100% relative humidity at the gas turbine input, resulting in the lowest temperature feasible without refrigeration (the wet bulb temperature). By allowing surplus fog into the compressor, direct high-pressure inlet fogging can also be employed to create a compressor intercooling effect, enhancing the power output significantly. This is made by Multistage Centrifugal pumps that increase the water pressure to the level required for injection. The centrifugal pump is operated as a speed-controlled injection pump. The frequency converter sets the speed of the injection pump based on the flow set point of the mass flow control. Figure 1 is showing a schematic diagram of inlet fogging process

The injection nozzles are located on a rack inside the inlet plenum. The nozzle rack consists of four individual lines, called “banks”, on which the nozzles are arranged. Two banks form a nozzle group. Each one of the four banks have an orifice outside of the inlet plenum. The orifices allow precision setting of the mass flow through the series-connected nozzles.

The banks of a nozzle group are combined to one line upstream of the orifices. The two connecting lines lead to the shutoff valves on the Wet Compression skid. Each of the connecting lines contains a filter (e. g.100 µm). The filters are used to remove constituent from the water located in the piping and valves of the skid downstream of the filter.

The discharge pressure of the injection pump is continuously monitored with the pressure transducers to trip the Wet Compression system when the average value exceeds the max allowed system pressure (e.g., > 85 bar). Furthermore, the Wet Compression system will be tripped if the pressure falls below the minimum allowed pressure (e.g., < 10 bar) for longer than e.g., 10 s. This minimum injection pressure (e.g., 10 bar) is required to maintain a sufficient vaporization.

The water injection flow is measured with the flow meter. The signal is used as a reference variable to control the injected water mass flow. The water mass flow control is integrated in the control electronics of the frequency converter as a PID controller. The set point is specified in the I&C of the gas turbine. The output signal of the flow meter is used for the speed set point of the frequency-controlled motor of the injection pump and for the gas turbine control system (OTC calculation and changing the temperature set point of the OTC control).

If the average value of the pressure transducers indicates that the pressure is too low (e.g., < 0,7 bar), startup of the water injection pump is blocked. If these occur for longer than e.g., 3 s during operation, the water injection pump is shut down because of the risk of cavitation. The pump is also shut down if its delivery rate as measured by flow meter drops below the required minimum flow rate (e.g., < 3,5 kg / s) for more than e.g., 5 s. This prevents the pump from overheating.

3. Wet bulb versus dry bulb

Most people are aware of how the dry bulb temperature fluctuates daily, but few are aware of how the wet bulb temperature varies in relation to the dry bulb temperature. Figure 2,3 and 4 shows that at low temperatures, the average wet bulb temperature is nearly equal to the dry bulb temperature, but as the temperature rises, the wet bulb temperature diverges more and more from the dry bulb temperature until it reaches a maximum of about (26.7 °C). BeniSuef levels have continuing to rise at extremely high temperatures.[18]

4. Daily variation of dry bulb, wet bulb, dew point and relative humidity

In the summer, the ambient conditions in BeniSuef alter dramatically during the day. the ambient temperature in the BeniSuef city region exceeds 40 degrees Celsius. In the summer, the fig. 2,3 and 4 depicts a sample of the temperature and humidity profile in the BeniSuef area. A large temperature difference of up to 17 degrees Celsius can occur during the day. The high temperature of more than 30 °C lasts for more than 7 hours , and hence it affects directly air density that in turn is directly proportional to air mass flow rate drawn by the compressor.[19]

Figures 2,3,4 show the hourly variations in dry bulb, wet bulb, and relative humidity for typical days of summer months in Al-korymat, BeniSuef, Egypt where the gas turbine plant is located. As shown in the figures, ambient temperature exceeds 40°C. A large temperature difference of up to 17°C can occur during summer days. The temperature continues more 30 for 7 hours during the day. The air density decreases due to this high temperature and thus reduces the flow rate of the air mass entering the compressor As shown in figures, the significant difference between dry and wet bulb temperatures during the afternoon hours, allows for using fog evaporative cooling for the air before entering compressor. [20]

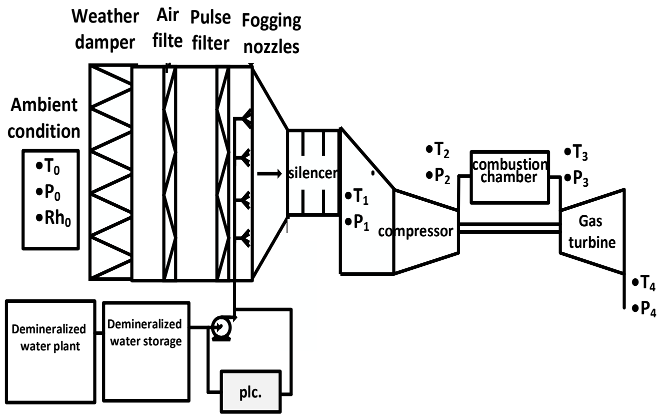

Figure 1: A schematic diagram of inlet fogging process

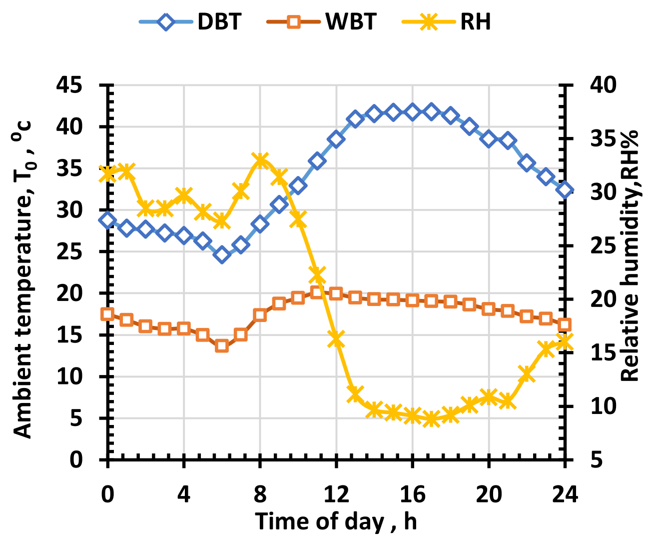

Figure 2: Daily Variation of Dry Bulb, Wet Bulb Temperatures, and Relative Humidity at BeniSuef on 15th May

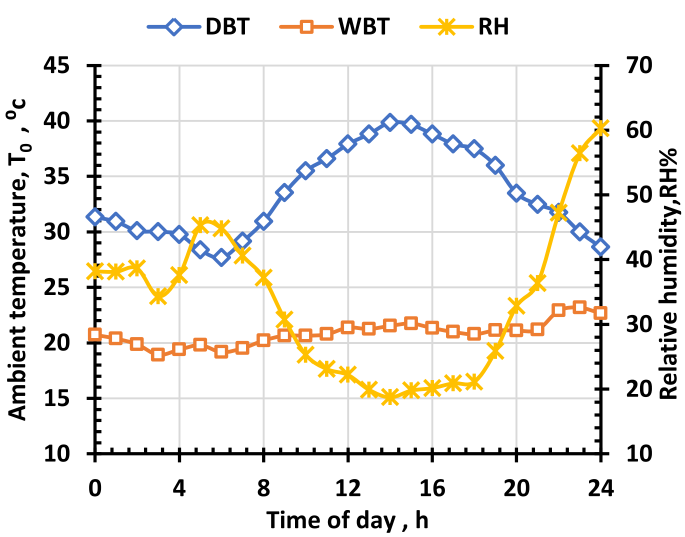

Figure 3: Daily Variation of Dry Bulb, Wet Bulb Temperatures, and Relative Humidity at BeniSuef on 1st June

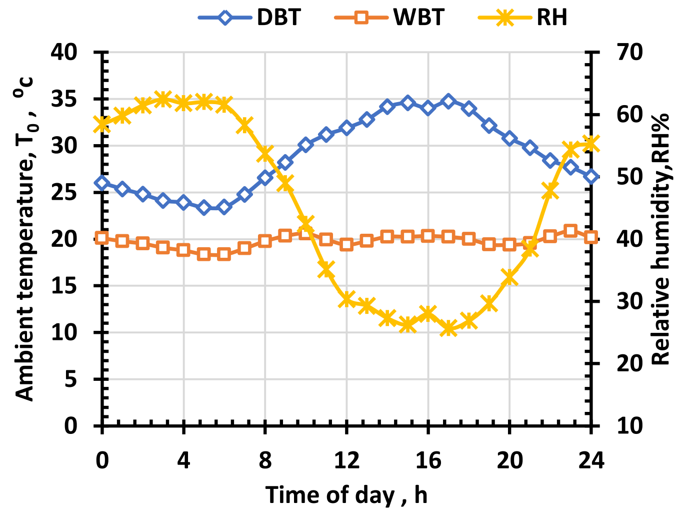

Figure 4: Daily Variation of Dry Bulb, Wet Bulb Temperatures, and Relative Humidity at BeniSuef on 20th June

5. Fogging cooling potential in BeniSuef, Egypt

Cooling degree-hours for a certain base temperature CDH_b are a measure of how much (in degrees) and for how long (in hours) outside air temperature is higher than a specific base temperature It can give an idea about the suitability of using evaporative cooling system for cooling the air inlet to the gas turbine unit in Korymat, BeniSuef, Egypt. It is calculated by equation (1) which is given in Ref. [21]

$$\mathrm{CDH}_b = \sum_{1}^{N} (T_i - T_b)^+ \quad (1)$$

where N is the number of hours in the day, T_i is the average hourly temperature, T_b is the base temperature of which the degree days are calculated. The “+” superscript sign indicate only positive values of the bracketed components are considered in the sum

Figure 5 show cooling degree-hours versus base temperature for three different base temperature 20, 24 and 26 for BeniSuef it is appear that most cooling potential lies in June July, august the results showed that for a base temperature of 20 °C, the degree hours for months of May, June, July, August, and September were 5934, 7070,7848, 7507, and 5520, respectively. It means that the potential of cooling gas turbine air by fogging system, is high in BeniSuef for 5 months in summer.

6. Evaporative cooling through the fogger on the psychometric chart

Figure 6 shows the two states of air entering and exiting from the fogging cooling system on the psychrometric chart. These cases are for several 188 hours of operation during May, June and July. From the psychrometric the temperature of the air entering the fogging cooling system ranged between 30 and 40 °C, and the relative humidity varied from 15 to 41%. For these inlet states, the outlet Temperatures leaving the fogging cooling system and entering the compressor ranged between 17 °C and 23 °C The fogging cooling system can reduce the temperature by an average value of 15 °C.

7. Methodology

The measured values at the power station are the dry and wet ambient temperatures, the inlet and exit temperatures of all components of the cycle, and the exit pressure of the compressor. Also, the fuel consumption, and the electric power after the generator were measured.

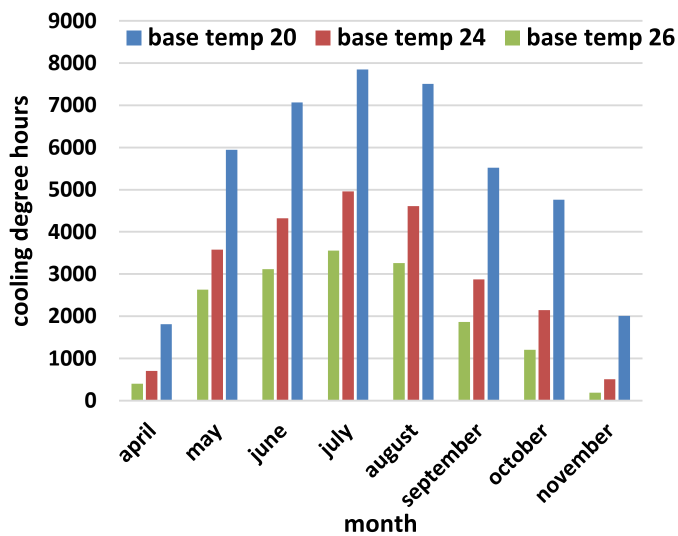

Figure 5: Evaporative cooling potential in BeniSuef Egypt for different base temperatures

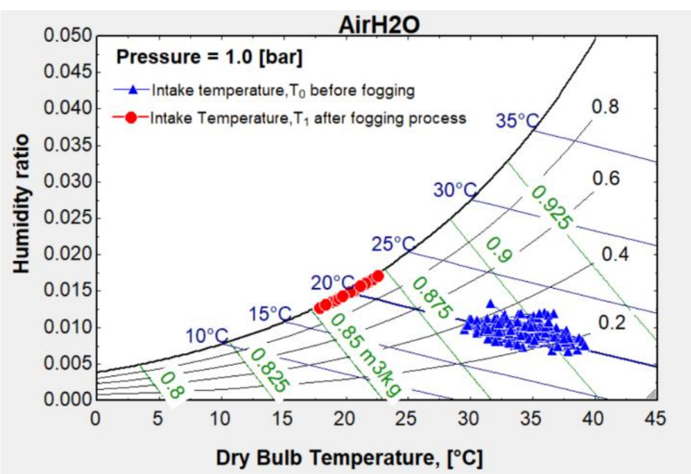

Figure 6: actual fogging process in psychrometric chart

Figure 7 shows the relative electrical power versus the air entry temperature of the compressor in the temperature range from 5 to 26 in the case of non-fogging operation and in the range of degrees from 16 to 30 in the case of foggy operation. It is noted that the power decreases linearly with the increase in compressor inlet temperature. That is for both non-fogging and fogging operating conditions. The data are more scattered in the case of foggy operation, may be due to the cooling effect inside the compressor resulting from the atomizer exceeding the saturation limit. At the same compressor inlet temperature, the power of non-foggy operation is 2 to3% higher than the power of foggy operation.[22][23][24]

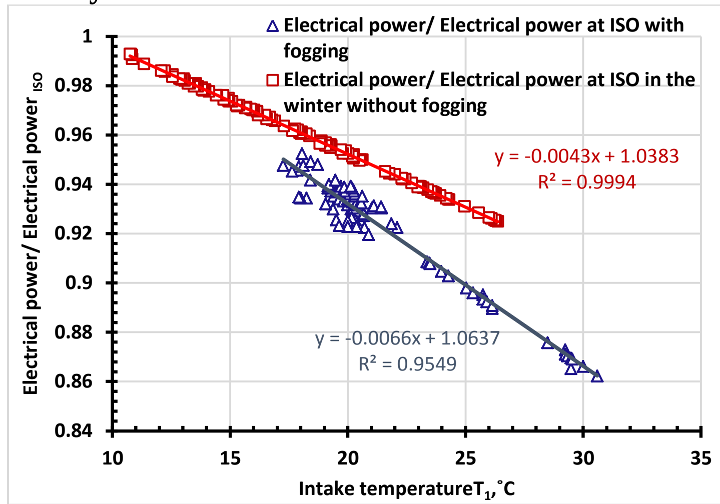

Figure 7: Electrical power per Electrical power at iso condition versus compressor inlet temperature with fogging and without fogging

Figure 8 shows the relationship between the air temperature at the exit of the compressor versus the temperature at its entry for the two operating conditions, with and without fogging. The figure shows that by reducing the compressor air entry temperature from 30 to 18 ^{0} C by using a fogger, the exit temperature decreases from 437 to 414, i.e., decreased by 5.3%, while if the inlet temperature without fogging decreases from 26 to 10 ^{0} C, the exit temperature decreases from 433 to 415, i.e., a reduction of 5.26%. It is noted that at the same inlet temperature, the exit temperature of the compressor is 1 to 2.5% higher in the case of the absence of fogger than in the existence of it.

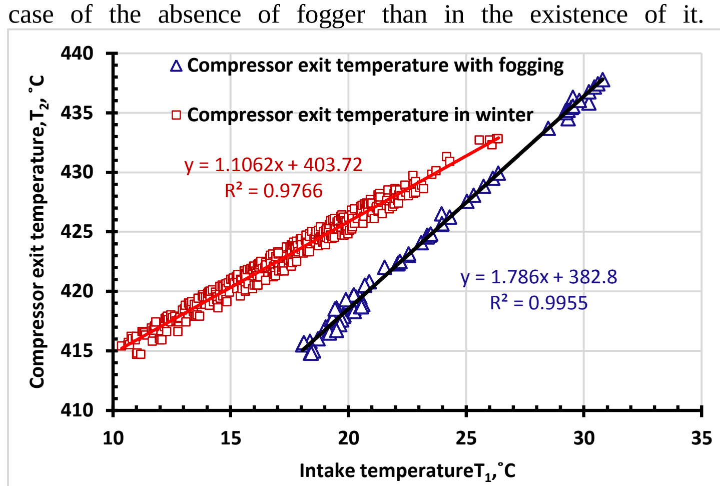

Figure 8: compressor exit temperature versus compressor inlet temperature with fogging and without fogging

Figure 9 shows the thermal efficiency versus intake temperature with and without fogging. As observed in the figure, at the same intake temperature the thermal efficiency increases about 1% to 2% when employing the fogging system.[25]

The electrical efficiency of the gas turbine η_e can be expressed as follows (2)

$$\eta_e = \frac{p_e}{\dot{m}_f LHV} \qquad (2)$$

where LHV is the fuel lower heating value and p_e is the net-work rate of the gas turbine cycle (MW) and $\dot{m}_f$ is the fuel mass flow rate (kg/s)

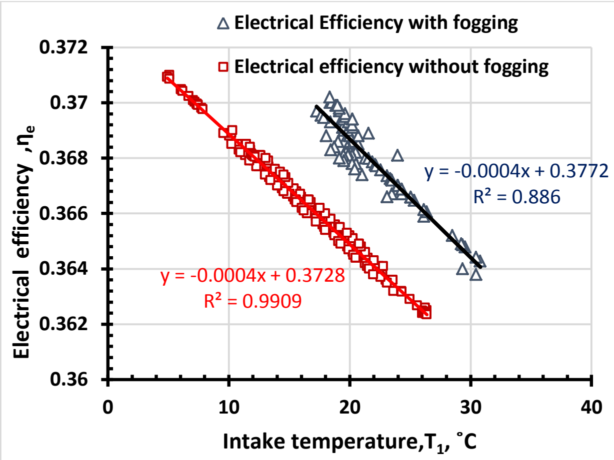

Figure 9: the electrical efficiency versus intake temperature with and without fogging

Figure 10 shows the effect of intake temperature on the specific fuel consumption of the gas turbine with and without fogging, the specific fuel consumption is calculated from equation (3), the specific fuel consumption increases 0.018% for every 5°C rises in intake temperature and as observed in the figure, at the same intake temperature the specific fuel consumption decreases 1.9% when employing the fogging system.

$$sfc = \frac{3600*\dot{m_f}}{p_e} \qquad (3)$$

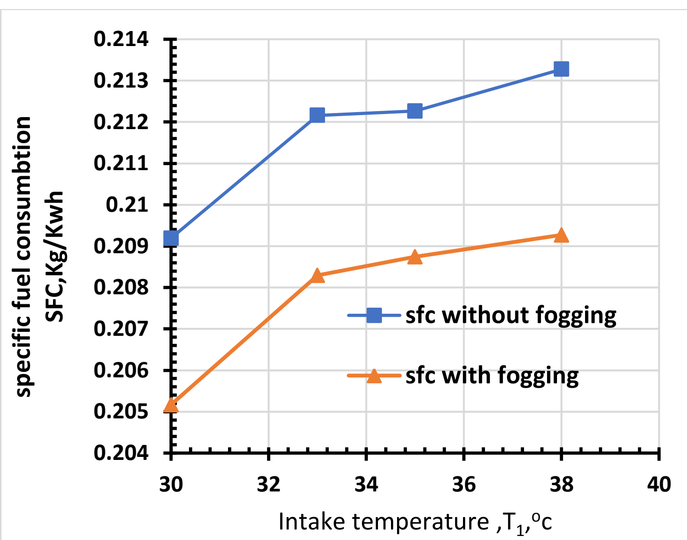

Figure 10: Effect of compressor intake temperature on specific fuel consumption of the gas turbine.

The estimated output power and first law efficiency for this power plant, as well as the corresponding recorded actual values under the identical operating conditions, are provided in Figs. (11 A,11B,11C,11D,11E,11F)and (12A,12B,12C,12D,12E,12E,12F).

in Figures (11 A,11 B,11 C,11 D,11 E,11 F) for the system with and without inlet fogging in May &June and Juley. It can be noted that using an inlet fogging system boosts output power by roughly 8% on average.

in Figures (12A,12B,12C,12D,12E,12E,12F). As can be seen, the first law efficiency variation is identical to the output power fluctuation and using the inlet fogging system enhances both output power and fuel flow rate. Because the percentage increase in fuel flow rate is less than the rise in output power, inlet fogging enhances first law efficiency. Over the course of three months, using an inlet fogging system increases output power generation and first law efficiency (May, June, and July). The average increases for these two metrics have been estimated to be roughly 8% and 2%, respectively the power gain by wet compression system is about 9000MWH during the three months.

Conclusions

This paper investigates the performance enhancement due to cooling the air entering the compressor of combined cycle power station located at BeniSuef, Egypt.

Fogging technique was utilized in this power station. In this paper the performance of the power station with fogger cooling was compared with the case without cooling. At first, to predict the potential of using such type of cooling in BeniSuef weather condition, the cooling degree hours were calculated for different base temperature. The results showed that for a base temperature of 20 C, the degree hours for months of May, June, July, August, and September were 5969, 7071,7848, 7507, and 5523, respectively. The average difference between the dry and wet bulb temperature during the period of fogger operation in summer was 17 ^{0} C in May and June. It means that there is high potential for cooling gas turbine air by fogging system, is high in BeniSuef for 5 months in summer.

Plotting the data on the psychrometric chart showed that the fogger can cool 640 kg/s air during summer from ambient air temperature ranged from 30 ^{0} C to 40 ^{0} C to a lower temperature ranged from 17 ^{0} C to 23 ^{0} C It means that there is high potential for cooling gas turbine air by fogging system, is high in BeniSuef for 5 months in summer.

According to the findings, using an inlet fogging system boosts output power generation and electric efficiency over the course of three months (May, June, and July). From the measured data in summer with fogger cooling, the power increased 0.78% for each 1 ^{0} C decrease in air temperature. While it is 0.42 % in winter.

The electric efficiency of the gas turbine cycle increases 0.11% for each 1 ^{0} C decrease in air temperature for the case of cooling with fogging and the case of cooling without fogging in winter. Cooling with fogging system showed an electric efficiency 1.1% higher than cooling in winter without fogging.

During operation with fogger cooler a 10 ^{0} C decrease in compressor inlet temperature leads to 20 ^{0} C decrease in outlet temperature. While the decrease is 12 ^{0} C in case of winter cooling.

using an inlet fogging system decreases the specific fuel consumption by 1.9%.

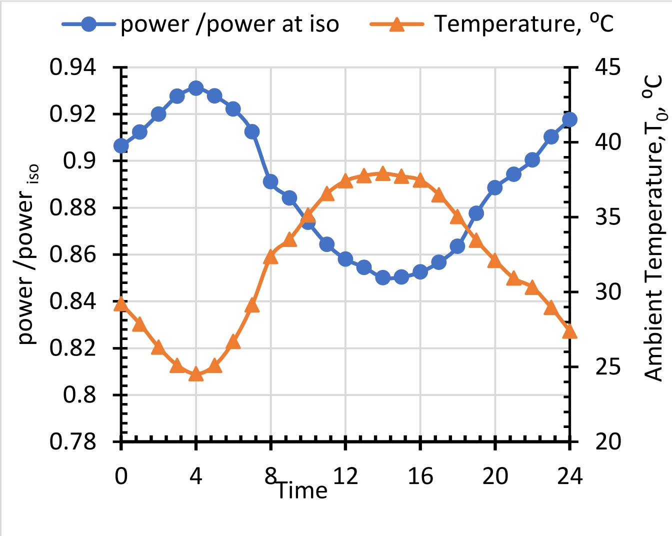

Figure 11: (A)Variation of power with time in case of no fogging, On 1st May

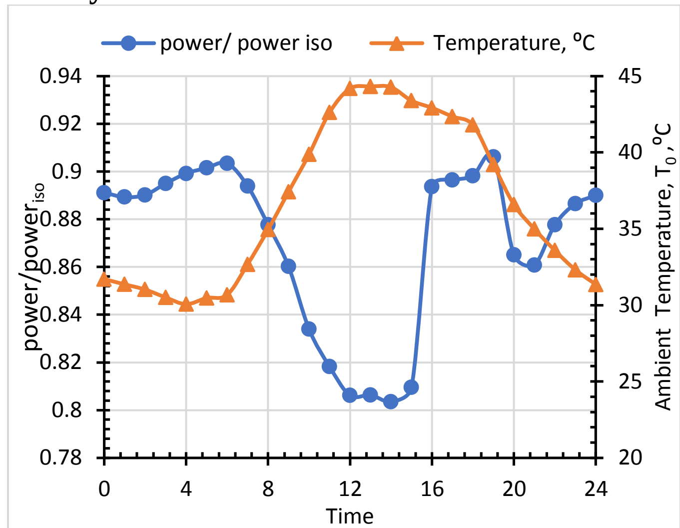

Figure 11: (B)Variation of power with time in case of fogging from 4:00 pm to 7:00 pm, On 5th May

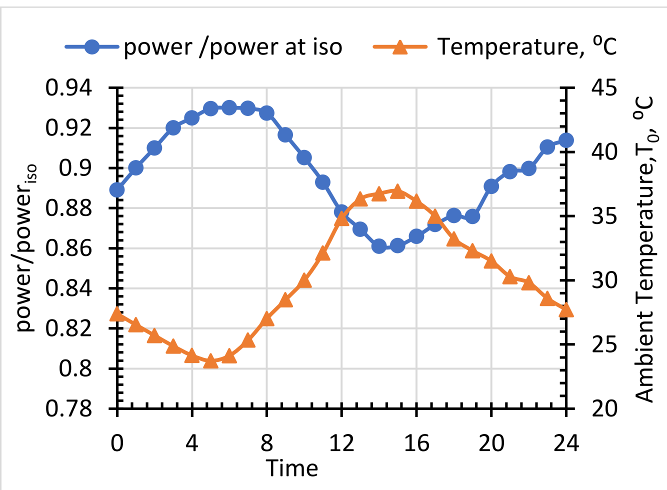

Figure 11: (C)Variation of power with time in case of no fogging, On 5th June

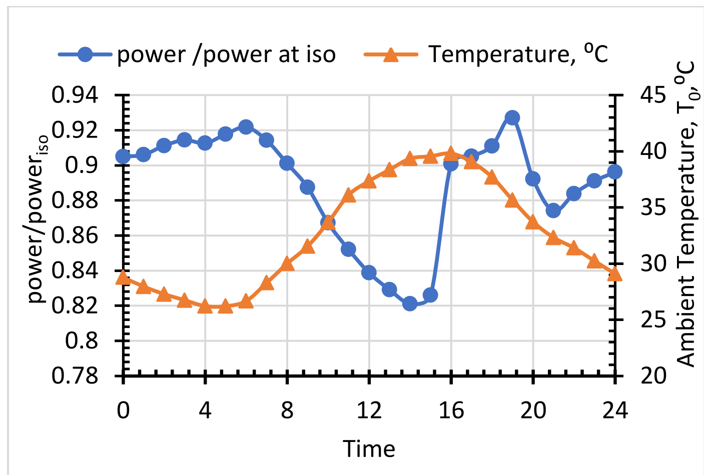

Figure 11: (D)Variation of power with time in case of fogging from 4:00 pm to 7:00 pm, On 1st June

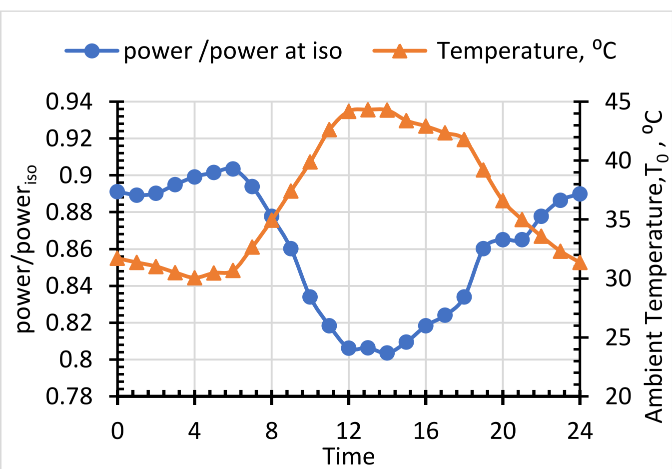

Figure 11: (E)Variation of power with time in case of no fogging, On 5th Juley

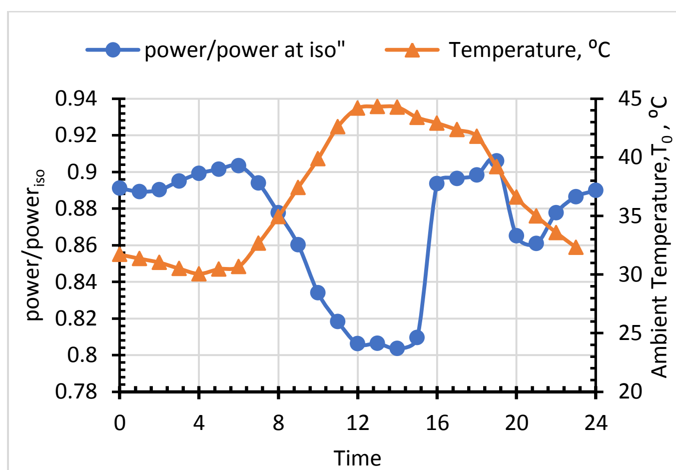

Figure 11: (F)Variation of power with time in case of fogging from 4:00 pm to 7:00 pm, On 1st Juley

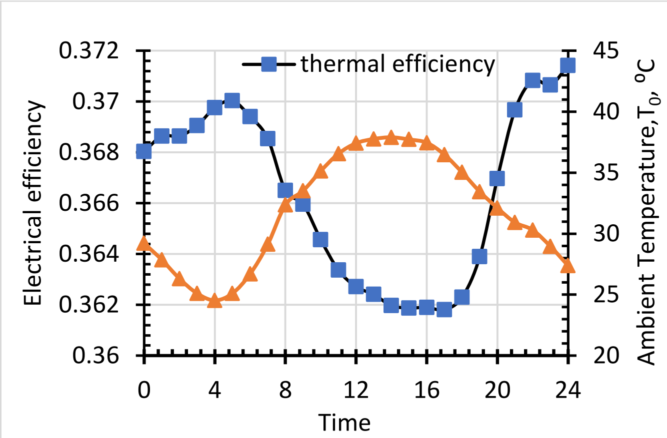

Figure 12: (A)Variation of thermal efficiency with time in case of no fogging, On 1st May

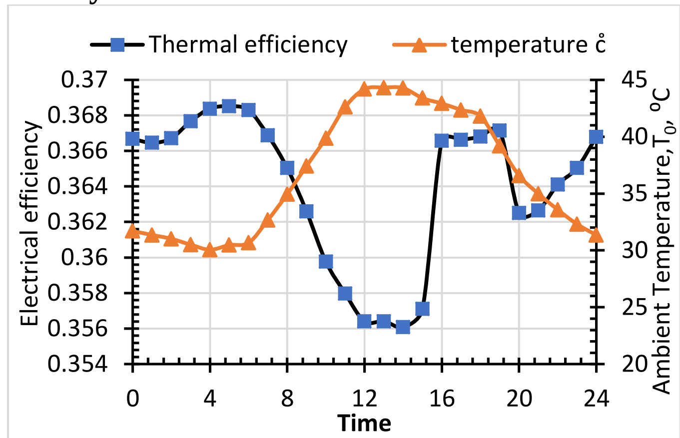

Figure 12: (B)Variation of thermal efficiency with time in case of fogging from 4:00 pm to 7:00 pm, On 5th May

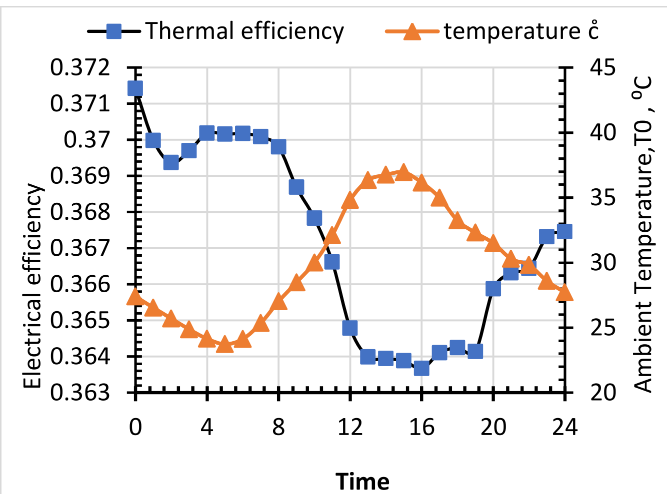

Figure 12: (C)Variation of thermal efficiency with time in case of no fogging, On 5th June

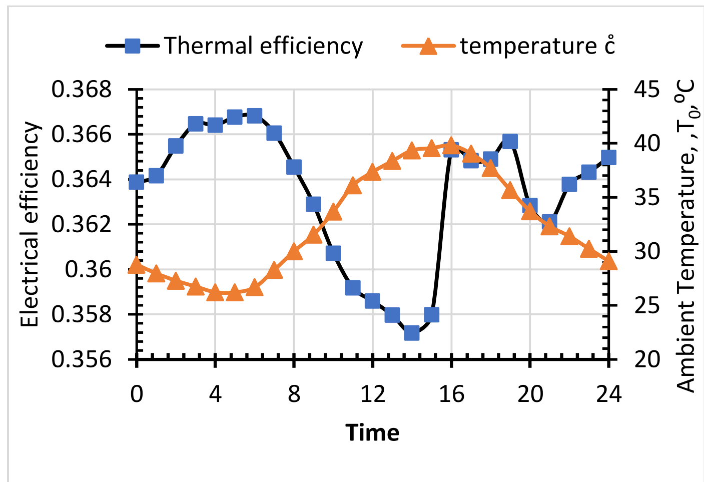

Figure 12: (D)Variation of thermal efficiency with time in case of fogging from 4:00 pm to 7:00 pm, On 1st June

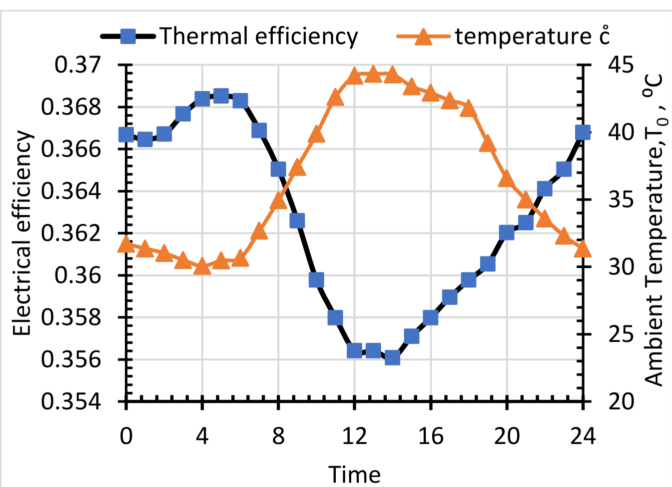

Figure 12: (E)Variation of thermal efficiency with time in case of no fogging, On 5th Juley

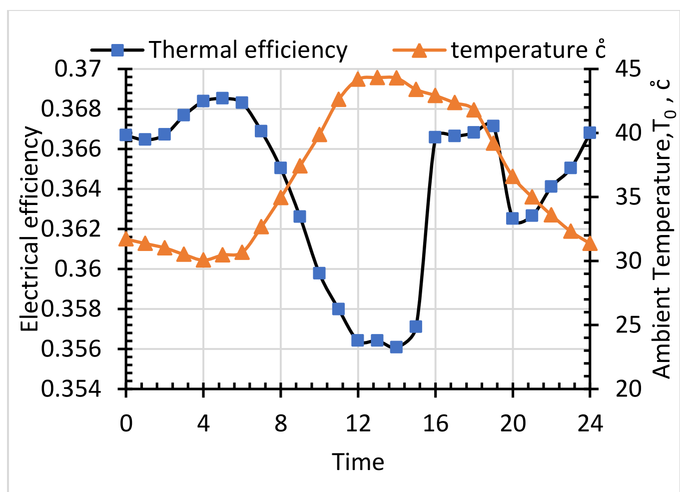

Figure 12: (F)Variation of thermal efficiency with time in case of fogging from 4:00 pm to 7:00 pm, On 1st Juley

1. Nomenclature

c_p	specific heat at constant pressure (kJ/kg)
$\dot{m}$	mass flow rate (kg/sec)
T	Temperature (°C)
WBT	Wet Bulb temperature (°C)
p_e	Net power output of the gas turbine (kW)

Abbreviations

CDHb	Cooling degree hour
DBT	Dry Bulb temperature (°C)
DP	Dew Point (°C)
ISO	Inlet standard condition
LHV	Lower heating value of the fuel (kJ/kg)
rpc	Compressor pressure ratio
RH	Relative humidity %
PLC	Program logic control
SFC	Specific fuel consumption[kg/kWh]
TIT	Turbine inlet temperature K

Greek symbols

η	efficiency
ω	the humidity ratio

Subscripts

0	Fogger inlet
1	Compressor inlet
2	compressor outlet
3	Gas turbine inlet
4	Gas turbine outlet
a	air
b	the base temperature (c)
C	compressor
e	electrical
f	fuel
g	gases
i	the average hourly temperature (c)

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