Improving the efficiency of the Zawia Combined Cycle Power Plant (ZCCPP) by using the fog cooling system

Abdulhafed Bn Jmaa[1*], Emad Khalfalla[2]
[1] abdujmaa@gmail.com, [2]emadk@zu.edu.ly
[1] Department of Mechanical Engineering, University of Zawia, Zawia, Libya
[2] Department of Mechanical Engineering, University of Zawia, Zawia, Libya

ABSTRACT

Cooling the air before it enters the gas turbine compressor for combined cycle power plants is an effective way to increase the power output of combined cycles in hot regions.

The gas turbines, power output drops of around 15% to 20% can be experienced when ambient temperatures reach 35°C, coupled with a heat rate increase of about 5%. This loss in output presents a significant problem to power generation gas turbines, when power demands are high during the hot summer months.

This paper presents a comparative analysis of the effect of air mist cooling techniques before entering the compressor in the gas turbine on increasing the output power of a combined cycle with the output of the gas turbines and the efficiency of the gas turbines during periods of high ambient temperature without using the fog cooling system.

The Zawia Combined Cycle Power Plant (ZCCPP) was taken as a model for applying the fog cooling system to the air inlet before it entered the compressor in the gas turbine. The air conditions were taken in terms of humidity and ambient air temperature at the highest temperature recorded in the year, which was in July. After analysis, it was found that the system The fog cooling increased efficiency and improved the overall performance of the (Combined Cycle Power Plant) CCPP.

1- Introduction

The output of Gas Turbine Combined Cycle (GTCC) is a strong function of the inlet air temperature. When the inlet air temperature drops, GTCC power output increases considerably and

heat rate varies slightly [1]. A simple strategy to improve GTCC performance under high ambient temperature is to employ GTCC Inlet Air Cooling (IAC) technologies [1].

Various inlet air cooling technologies, such as evaporative coolers and refrigeration chillers, have been implemented and operated widely [3]. Evaporative coolers include evaporative media coolers, through which compressor inlet air passes and cools; s water spray coolers or fogging systems, including saturated evaporative coolers and overspray or over fogging systems. As far as heavy-duty gas–steam combined cycle power plants are concerned, much effort has been made to evaluate inlet air cooling technologies from the viewpoint of economics and thermodynamics air chillers for combined-cycle operation using mechanical vapor compression refrigeration systems [2].

2- Technology Overview

By evaporating billions of micro fine droplets in the gas turbine inlet duct, adiabatic cooling is attained and the evaporative effect results in a drop in inlet temperature, resulting in gas turbine power augmentation and an increase in gas turbine efficiency as shown in Figure (1). Depending on the type of combustor utilized, there is also a considerable reduction in Nitrogen Oxides (NOx) Emissions levels.

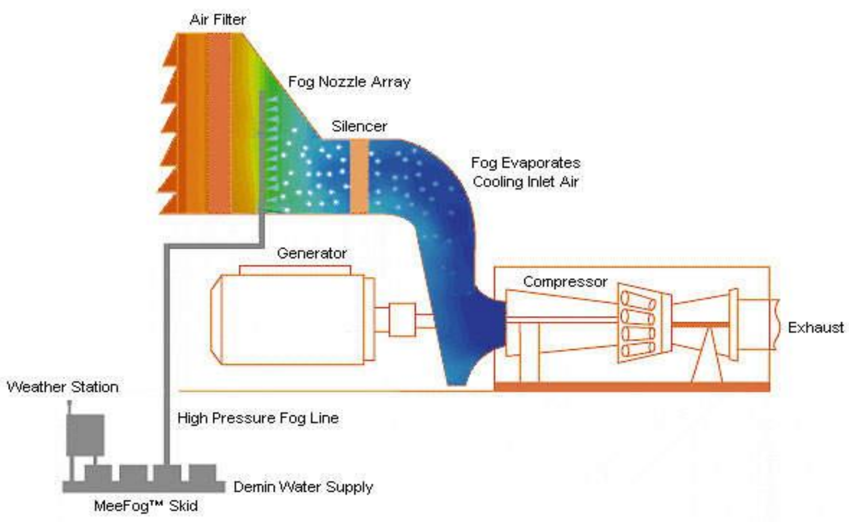

Figure (1): Fog System Diagram. [6]

Benefits of utilizing fogging System include

i. Immediate Measurable Power Augmentation
ii. Lower Heat Rate
iii. Rapid Temperature Drop
iv. Increased Compressor Wash and Maintenance intervals
v. Practically no Induced Inlet Pressure Drop
vi. Low Capital Cost and Rapid Payback

Turbine output and efficiency of gas turbines is reduced during periods of high ambient temperature. This creates a need to overcome the inherent loss of gas turbine output during this crucial period when enhanced power is most required. Peaking power plants also need to augment power during high demand periods. High-pressure inlet fogging fits this niche of an effective power augmentation technology at a relatively low cost with substantial benefits.

The power output drops of around 15% to 20% can be experienced when ambient temperatures reach 35°C, coupled with a heat rate increase of about 5%. This loss in output presents a significant problem to power generation gas turbines, when power demands are high during the hot summer months. In the petrochemical and process industries, the reduction in power of gas turbines considerably curtails plant output. Inlet fogging is the most cost-effective approach to mitigate this issue.

Direct inlet air fogging of gas turbines an effective method of cooling as shown in Figure (2). Demineralized water is pressurized to a constant operating pressure of 138 Bar and converted into “Fog” by means of special atomizing nozzles. The fog provides cooling when it evaporates in the air inlet duct of the gas turbine and adds to the Air Mass Flow. This technique allows 100% effectiveness in terms of attaining close to wet bulb temperatures.

Figure (2): fog system in air intake gas turbine. [6]

The fogging is a method of inlet cooling where demineralized water is converted into fine fog droplets by means of specially designed atomizing nozzles operating at pressures between, 69 to 207 bar. As the fog evaporates in the intake duct, it cools the air. This technique can achieve close to 100% evaporative cooling effectiveness in terms of attaining the wet-bulb temperature at the compressor inlet under design conditions [2].

A typical high pressure fogging system consists of:

- A high-pressure pump skid with associated pumps and controls.
- A set of fog nozzles located in the intake duct after the filters.

Each impaction pin nozzle in the array produces billions of droplets per second creating a fog as shown in Figure 3.

Figure 3. Typical Gas Turbine Inlet Fogging Skid (6)

3- Zawia Power Plant Description.

The power plant under study is located in the west of Libya, in Zawia City. Name of power plant Zawia Combined Cycle Power Plant (ZCCPP) exploited in 1999 with four gas turbine units. In 2004, two other gas turbines added to the existing units, and finally in 2008 three steam turbines, and six heat recovery steam generative (HRSG) overall capacity of 1275 MW which is the biggest power generation station in west of Libya, and also it is one of the most important centres of electricity production in General Electric Company of Libya (GECOL) fog as shown in Figure 4.

Figure 4: Scheme of the Zawia Combined Cycle Power Plant. (7)

Each combined cycle composed of these units: two Alstom gas turbines; model GT13E2 with

nominal capacity of 159 MW, two Hyundai Engineering Company (HEC) heat recovery
boilers and a Fuji Electric Company steam turbine with nominal capacity of 130 MW.[4]
According to Zawia combined cycle power plant (ZCCPP) data, average weather conditions in Zawia combined cycle power plant site is at 22 ° C and relative humidity 55%, so these basic conditions considered as a design point [7].
In this paper simulation of the power plant is done by Thrmoflow package software, version.

3-1 Climatic Data Analysis

The weather data for the Zawia region in Libya has been analyzed. The initial focus is on
summer months, as these are the months when the GT output drops significantly with the high ambient temperatures. Consequently, considerable augmentation of gas turbine output power will be attained during the summer A sizable number of Evaporative Cooling Degree Hours
(1 ECDH = 1ºC WBD x 1hr) are available in the year at the site as shown in Table (1).
For calculation purposes, the available weather data for the region has been considered.

J	F	M	A	M	J	**J**	A	S	O	N	D	**Annual Total**
244	620	1710	3030	4602	4993	**5087**	4954	4274	3582	2103	785	**35,984**

Table (1): Monthly and Annual ECDH for Zawia City (Min. WBT=12.8ºC). [5]

The system in consideration has been designed for a Dry Bulb Temperature of **36ºC** and a “Coincident” Wet Bulb Temperature of **19ºC (19% RH)**. These conditions give the most favorable benefits for the available evaporative cooling potential at the site.

4- Simulation Summary for 1 x Alstom GT13E2

The GT- Pro program was used to analysis the data taken from the Zawia Combined Cycle Power Plant, and the month with the highest temperature was selected, and the highest air entry temperature for the compressor was recorded based on the data taken from the Zawia Combined Cycle Power Plant, which is in the month of July.

The following assumptions were identified

Gas Turbine Model : Alstom GT13E2 Power Generation Turbine

Assumptions: Natural Gas | PR 14.6 | LHV HR 9,896 kJ/kWh, Eff. 36.4% GT @ 100 % rating, inferred TIT control model, CC limit Total inlet loss = 10 millibar,

Exhaust loss = 12.45 millibar Duct & stack = 0, HRSG = 0 millibar

Fuel Type:Natural Gas, GT Mode: Simple Cycle, GT-PRO ID No.285

1.The following are simulation results for a new, good and clean GT model operating under ideal conditions. They are given with the intention to predict performance and do not constitute any compliance or guarantee in any form.

2.Model has been run as a Simple Cycle configuration for 36ºC ambient Dry Bulb and 19ºC ambient Wet Bulb with cooling potential of 17ºC.

3.Without detailed process information,. This will result in an analysis that will provide a good trend of the improvement in performance with fogging as shown in figure (5).

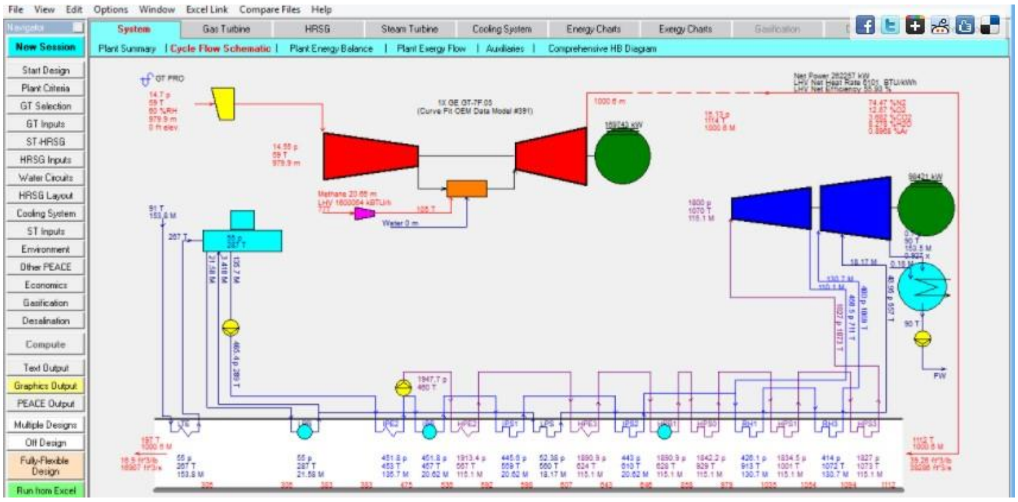

Figure (5): GT-PRO software for Combined Cycle power plant

4-1 Proprietary Information

The following cases have been simulated:

[A] Base Case, 36ºC & 19% RH Ambient, No Fogging

[B] 36ºC & 19% RH, 19ºC Depression, Evaporative Fogging

4-2 Simulation Summary for 1 x Alstom GT13E2

The results of the analysis using the GT-Pro program indicate that the difference between the two cases, in the first case using the fog system, the produced energy is 144.063 MW, while the energy produced using the fog cooling system is 162.447 MW, an increase of 12.76%. We note as 1 you a decrease in the amount of air entering and therefore an increase in efficiency. As shown in the following table (2).

Parameter	[A] Base Case, 36ºC&19%RH Ambient, (No Fog)	[B] evaporative fogging to saturation *(with fog)*	*% change Evap fogging (with fog)*
Plant Output *Net kW*	144,063	162,447	12.76% ***{10.85%*}***
Plant Heat Rate, Lhv *Net kJ/kWh*	10,604	10,249	(-3.35%) ***{-2.85%*}***
Air Mass Flow *kg/sec*	487.9	514.1	5.37%
Lhv Net Efficiency (%)	33.95	35.13	1.18%

Table (2): Simulation summary table

Power Gain at design values with Fogging to Evap Level = 18,384 kW {15,626.4 kW*}

Heat Rate Reduction with Fogging at Design Condition = 355 kJ/kWh {301.8 kJ/kWh*}

5- Conclusions

The benefits of using fogging system for power augmentation include:

1- Minimizing Peak Load operation

Currently, gas turbines being operated at various sites during the summer are forced to operate at higher temperatures when demand for power is at its peak. The higher firing temperatures that arise from such continuous operation result in a damaging effect on hot section life. This can easily reduce (shorten) the maintenance intervals by 20%, meaning more frequent maintenance.

2- Increased availability of Process Machinery

As there will be more power available, the overall availability of the down-line Process, where applicable, will also increase and the need to curtail operations will diminish (or even disappear).

3- Reduced Gas Turbine Heat Rate

Operating at reduced Inlet air temperatures also results in a significant reduction in gas turbine Heat Rate. This results in more efficient use of fuel.

4- Lower NOx Emissions

By increasing the water vapor content of the combustion air, inlet fogging causes a significant

decrease in both specific and total NOx emissions, regardless of whether the fog system is
used as an evaporative cooling system or for additional Compressor Intercooling.

5– Longer Intervals between Compressor Washes and Maintenance

The saturated air at the Compressor Bellmouth performs a soft cleaning action on the

Compressor initial stages and reduces the necessity of frequent online water washing

6- Recommendations:

1- The simulation results are very much dependent upon the condition of the Turbine and its operating procedures. They are typical for a new, good and clean turbine operating under ideal conditions. Actual results may be less. The GT Performance Improvement at site conditions, so I recommend that future studies take into account the age of the power plant.

2- The cost has not been accurately calculated in this paper, so it is recommended that the cost of equipment for the fog system be taken into account.

3- Simulation run results for a typical Alstom GT13E2 gas turbine are previously presented. Therefore, it was suggested to take into account the maintenance of the turbine in future studies.

4- I recommend that the fog cooling be used in desert places where there is sufficient water for cooling, where the results are better due to the humidity.

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