Effect of Ambient Temperature on the Performance of Gas Turbines Power Plant

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Abstract

Efficiency and electric-power output of gas turbines vary according to the ambient conditions. The amount of these variations greatly affects electricity production, fuel consumption and plant incomes. The purpose of the present study is to investigate the effect of the ambient temperature on the performance of gas turbines. We observed that the power decreases due to reduction in air mass flow rate (the density of the air declines as temperature increases) and the efficiency decreases because the compressor requires more power to compress air of higher temperature.

Keywords: *Gas Turbine, Combined cycle, configuration System, Efficiency*

1. Introduction

Several gas turbines are being widely used for power generation in several countries all over the world. Obviously, many of these countries have a wide range of climatic conditions, which impact the performance of gas turbines [1]. Gas turbines are increasingly used in combination with steam cycle, either to generate electricity alone, as in combined cycles, or to cogeneration both electrical power and heat for industrial processes [2]. A combined cycle featuring one or several gas turbines and a steam cycle is a power plant option commonly used for power production that offers high efficiency.

Kakaras [3] reported that the gas turbine output and efficiency is a strong function of the ambient air temperature. Depending on the gas turbine type, power output is reduced by a percentage between 5 to 10 percent of the ISO-rated power output (15^{o}C) for every 10 K increase in ambient air temperature. At the same time the specific heat consumption increases by a percentage between 1.5 and 4 percent. Lamfon [4] investigated the performance of a 23.7 MW gas turbine plant operated at ambient temperature of 30 to 45^{o}C. The net power output is improved by 11 percent when the gas turbine engine is supplied with cold air at the inlet. At the ambient temperature of 30^{o}C the net power output increases by 11 percent at ISO-rated condition, accompanied by a 2 percent rise in thermal efficiency and a drop in specific fuel consumption of 2 percent.

Mohanty [5] presented that by increasing the inlet air temperature from the ISO-rated condition to a temperature of 30^{o}C, would result in a 10 percent decrease in the net power output. For gas turbine of smaller capacities, this decreased in power output can be even greater. He also indicated that a rise in the ambient temperature by 1^{o}C resulted in 1 percent drop of the gas turbine rated capacity

Ameri [6] reported that in a 16.6 MW gas turbine when the ambient temperature decrease from 34.2^{o}C to ISO-rated condition, the average power output can be increased by as much as 11.3 percent. He also indicated for each 1^{o}C increase in ambient air temperature, the power output will decrease by 0.74 percent.

Dawoud [7] presented the results from the study of gas turbine plant in two locations in Oman. The results showed that fogging cooling is accompanied with 11.4 percent more electrical energy in comparison with evaporative cooling in both locations. On the other hand, absorption cooling offers 40 percent and 55 percent more energy than fogging cooling.

Aihazmy [8] reported that an average power output increment of 0.57 percent for each 1^{o}C drop in inlet temperature. The power output is increased by 10 percent during cold humid conditions and by 18 percent during hot humid condition.

Boonnasa [9] presented the results from the study of combined cycle power plant operated in Bangkok. The results showed that decreasing temperature from 35^{o}C to ISO-rated condition increase the power output of a gas turbine by 10.6 percent and the combined cycle power plant by 6.24 percent annually. The gas turbine was rated at 110.76 MW.

2. System configuration

The plant consists of two gas turbines with type of PG6581B and rated capacity of 38 MW, one unit of steam turbine with rated capacity of 36 MW and heat recovery steam generator (HRSG) is made by Harbin Boiler Works (China). Heat Recovery Steam Generator (HRSG) is the important component of combined cycle power plant used to recover waste heat from the high temperature of the exhaust of the gas turbines and generate steam .High efficiency; low energy losses and long expected life are the important factors which make combine cycle power plants unique in compression with other type of plants. The steam turbine type L36-6.70 is also the product of Nanjing Turbine & Electrical Machinery Group Co .Ltd. Other main ancillary systems consist of air compressor system, firefighting system, potable water generation plant, waste water treatment plant, heating ventilation and air condition (HVAC) SYSTEM. DC system, uninterruptible power supplies system (UPS), etc. A schematic diagram of the plant is shown in Fig 1.

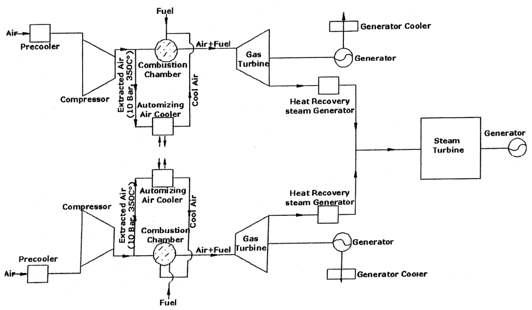

Fig. 1 Diagram for gas turbines in power plant

4. Parameters of Main Equipments

4.1 Gas turbine generator unit

The gas turbine generator unit was manufactured by Nanjing Turbine Group Company limited. The power output is 32.551MW under the following design condition:

Ambient temperature	40°C
Atmosphere pressure	0.966 bar
Ambient humidity	38%
Inlet air pressure drop	100 mm H_2O
Exhaust pressure drop (under combined cycle)	350 mm H_2O
Fuel	Light diesel oil (LDO)
Power factor	0.80
Rated frequency	50 Hz

4.2 Heat recovery steam generator

The HRSG was supplied by Harbin marine boiler & turbine research institute. The HRSG output parameters are:

Maximum continues output	63.78 t/h
Output steam temperature	6.9 M Pa
Output steam temperature	468°C
Exhaust gas temperature	<154°C
Feed water temperature	104 °C

4.3 steam turbine generator unit

Steam turbine also was manufactured by Nanjing Turbine Company limited. It is a single case, condensing type turbine. The main parameters are as followings:

Main steam pressure	6.7 M Pa
Main steam temperature	456°C
Rated process steam flow	6 t/h
Process steam pressure	0.9 M Pa
Process steam temperature	244.3°C
Rated main steam flow	127.56 t/h
Exhaust steam pressure	0.0099 M Pa
Generator power factor	0.80
Frequency	50 Hz

4.4 The Effect of Ambient Temperature on Efficiency

The data used for the analysis is obtained from the manufacturer data sheet of power plant [10, 11].
All the finding obtained from plant was analyzed. The analysis showed results (Table I), which have been plotted in graphs, Figure (2 and 3). The graphs provide and depict result of the calculated power output and efficiency. The calculations took into account the average reading of nine days for each month.

Table 1: Effect of ambient conditions on performance, years (2006-2007)

	Month	**Ta°C Average**	**Heat input (KJ)-Average**	**Heat output (KJ)-Average**	**Efficiency %**
2006	3	28.5	4.68E+10	1.54E+10	36.48
	4	31.5	4.91E+10	1.80E+10	36.77
	5	34	5.01E+10	1.69E+10	34.5
	6	34	4.30E+10	1.55E+10	36.25

	7	32	4.97E+10	1.78E+10	35.79
	8	31	5.00E+10	1.77E+10	35.32
	9	32.5	4.74E+10	1.72E+10	36.35
	10	32	4.33E+10	1.60E+10	37.17
	11	27.5	2.55E+10	1.01E+10	36.75
	12	24.5	4.74E+10	1.69E+10	37
2007	2	22	3.91E+10	1.48E+10	38.02
	3	25	7.72E+10	1.73E+10	37.87
	4	31	5.27E+10	1.83E+10	35.86
	5	35	5.54E+10	2.22E+10	36.84
	6	33	5.13E+10	1.80E+10	40.11
	7	27	5.87E+10	2.45E+10	42.89
	8	28	5.80E+10	2.18E+10	41.92
	9	31	5.89E+10	2.63E+10	38.01
	10	31	4.86E+10	1.87E+10	38.42
	11	30	4.44E+10	1.71E+10	40.94
	12	26	4.95E+10	2.05E+10	41.09

The output heat (Q_{out}), input heat (Q_{in}) and thermal efficiency (η_{Th}) are calculated by equation (1-3).

$$Q_{out}(KJ) = Q_{out}(MWh) \times 10^3 \times 3600 \quad (1)$$

$$Q_{in}(KJ) = M_{LPG} \times Low(CV)_{LPG} + M_{LDO} \times (CV)_{LDO} \quad (2)$$

$$Low(CV)_{LPG} = 45125 Kj / Kg$$

$$Low(CV)_{LDO} = 42679.2 Kj / Kg$$

$$\eta_{Th} = \frac{Q_{out}}{Q_{in}} = \frac{Q_{out}}{M_{LPG} \times Low(CV)_{LPG} + M_{LDO} \times Low(CV)_{LDO}} \quad (3)$$

Where M_{LPG} is the mass of liquid petroleum gas, $(CV)_{LPG}$ calorific value of liquefied petroleum gas, M_{LDO} mass of light diesel oil, and $(CV)_{LDO}$ calorific value of light diesel oil .

5. Results and discussions

From figure 2: illustrates the variation of temperature and efficiency during the whole year. In March when the temperature is 28.5°C the corresponding efficiency is 36.48%, for April the efficiency is nearly same as March, but when the temperature increases the efficiency decreases as shown in May and June (summer season). For the remaining months of the years; September, October, November and December the efficiency is observed to as the temperatures drops in those months.

From figure 3: the efficiency decreases gradually as the average temperature increase from February to April. In July the efficiency reach maximum value when the ambient temperature is 27°C due to the rainy season. The efficiency then decrease again in September and October due to increasing in the temperature. The efficiency again rises as the temperature drops in December (winter season).

In general the ambient conditions under which a gas turbine operates have a noticeable effect on both the power output and efficiency.

It is clear from the above that the efficiency is greatly affected by the ambient temperature of the air entering the compressor.

There is variation in power and efficiency for a gas turbine as a function of ambient temperature compared to the reference international organization for standards (ISO) condition at sea level and 32.78 °C.

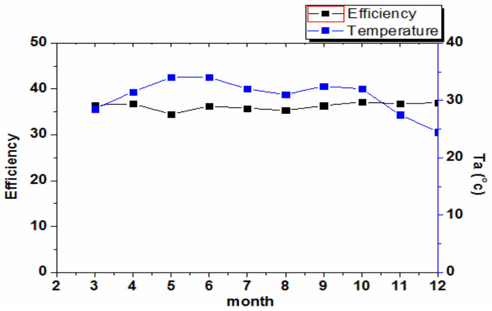

Fig. 2 Thermal efficiency and ambient temperature during the year (2006)

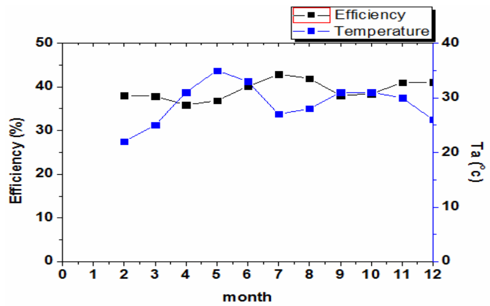

Fig. 3 Thermal efficiency and ambient temperature during the year (2007)

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