Inlet temperature effect on Electric Power Production from gas turbine power plants in Kurdistan-Iraq

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ABSTRACT

The demand for electric power is significantly high during the hot summer season. Electric-power output of simple cycle gas turbines vary according to the inlet conditions. The amount of these variations greatly affects the production of electricity. Therefore, the variation of inlet temperature will effect on the electric power production. For this purpose, simple cycle gas turbines in three stations are demonstrated in this study. Each station contains four units with 125 MW power output for each unit. The units were designed to produce 125 MW at standard design conditions (sea level, 15 °C, 1.013bar, 60% relative humidity). While, the operation conditions in Kurdistan region recorded highest ambient temperature. The objective of this study is to analysis the power output of the stations based on the variation in the inlet temperature. The results show that the losses in electricity production occur in all regions during the periods that the temperature is above the standard design temperature and loss up to 21.6 % depending upon the regions. While, the average power output of the plant decreases by 0.91 % for each 1 °C increase in inlet temperature.

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 the gas turbines. The standard air conditions in a gas turbine designing are (sea level, 15 °C, 1.013bar, 60% relative humidity) (Amir and Ali , 2006).

The General Electric (GE FRAME 9E) model is a simple cycle, single shaft gas turbine with 14 reverse-flow combustors. The MS9001 gas turbine assembly consists of six major sections or groups, namely: the fresh Air inlet, Compressor, combustion system, turbine, exhaust and the support system (Khor Al Zubair,2005).

The amount of electricity production is very important for the companies during peak demands. Because during peak period the sale
prices will be high, it raises the income and profit. However, the amount of electricity production is not constant in power plants, it is affected by ambient conditions (temperature, pressure and relative humidity), and that depends on the plant type and characteristics. Ambient air is used directly as the working fluid in the system. Gas turbines are the most affected ones in all conventional power generation systems. The effect of temperature is more significant than other ambient conditions (Loud and Slaterpryce, 1993).

Gas turbines are designed for standard air conditions. However, operating periods at off-design conditions are much greater than that at design conditions. If operating periods at off-design conditions last for extended periods, especially depending on the place where gas turbine is installed, measures for performance enhancement should be taken. Compressor inlet air cooling has been discussed in various studies (Gareta et al., 2001).

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°C), for every 10 oC increase in ambient air temperature. At the same time, the specific heat consumption increases by 1.5 to 4 percent (Kakaras, 2006).

The study of the performance of gas turbine operating in hot humid conditions of Jeddah in Saudi Arabia show that the average power output of the plant increases by 0.57 % for each 1 oC drop in ambient air temperature, the power output is increased by 10 percent under the standard conditions of gas turbine (Alhazmy and Najjar, 2004).

Gas turbine design parameters, compressor pressure ratio and turbine inlet temperature (TIT), determine the effect of ambient conditions on the performance. Gas turbines used in electric-power generation are manufactured in two classes which are heavy-duty and aero derivative. These two classes of turbines have differences in performance, cost and partial load behavior, as well as performance variations with the ambient temperature (Chaker et al., 2003).

Investigated the performance of gas turbine cycle by intake air cooling using absorption chiller in the weather data of Bangkok. Investigation reported, as reducing the cycle inlet temperature from ambient air condition to 15°C increases the instantaneous power output between 8 and 13% as result 11% additional electricity generated from the same gas turbine power plant (Mohanty and Paloso, 1993).

The purpose of this study is to analyses the effect of compressor inlet temperature on the performance of the gas turbine power output of the plant. Simple cycle gas turbines in three stations are considered in this study. Each station developed 500 MW from four units, each unit delivers 125 MW. In this research, power output changes of gas turbine within the inlet temperature effect have been analyzed. Results obtained from the analysis presented and discussed in the terms of power output.

2. LITERATURE SURVEY
2.1. Thermodynamic Principles

A schematic diagram for a simple-cycle, single shaft gas turbine is shown in Figure 1. Air enters the axial flow compressor at point 1 at ambient conditions. Since these conditions vary from day to day and from location to another, it is convenient to consider some standard conditions for comparative purposes. The standard conditions used by the
gas turbine industry are 15°C, 1.013 bar and 60% relative humidity, which are established by the International Standards Organization (ISO) and frequently referred to as ISO conditions. Air entering the compressor at point 1 is compressed to some higher pressure. No heat is added; however, compression raises the air temperature so that the air at the discharge of the compressor is at a higher temperature and pressure (Frank, 2007).

Figure 1: Schematic diagram of a simple-cycle, single-shaft gas turbine.

Upon leaving the compressor, air enters the combustion system at point 2, where fuel is injected and combustion occurs. The combustion process occurs at essentially constant pressure. Although high local temperatures are reached within the primary combustion zone (approaching stoichiometric conditions), the combustion system is designed to provide mixing, burning, dilution and cooling. When combustion mixture leaves the combustion system and enters the turbine at point 3, it is a mixed average temperature. In the turbine section of the gas turbine, the energy of hot gases is converted into work. This conversion actually takes place in two steps, in nozzle section of the turbine, the hot gases are expanded and a portion of the thermal energy is converted into kinetic energy. Second in the subsequent bucket section of the turbine, a portion of the kinetic energy is transferred to the rotating buckets and converted to work. Some of the work that developed by the turbine are used to drive the compressor, and the remainder is available for useful work at the output flange of the gas turbine. Typically, more than 50% of the work developed by the turbine sections is used to power the axial flow compressor. As shown in Figure 1, single-shaft gas turbines are configured in one continuous shaft and, therefore, all stages operate at the same speed. These units are typically used for generator drive applications where significant speed variation is not required (Frank, 2007).

2.2. The Brayton Cycle

The thermodynamic cycle where all gas turbines operate upon is called the Brayton cycle. Figure 2 shows the classical pressure-volume (PV) and temperature-entropy (TS) diagrams for this cycle. The numbers on this diagram are the same as the numbers used in Figure 2. Path 1 to path 2 represents the compression occurring in the compressor, path 2 to path 3 represents the constant-pressure addition of heat in the combustion systems, and path 3 to path 4 represents the expansion occurring in the turbine. The path from 4 back to 1 on the Brayton cycle diagrams indicates a constant-pressure cooling process. In the gas turbine, this cooling is done by atmosphere, which provides fresh and cool air at point 1 on a continuous basis in exchange for the hot gases exhausted to the atmosphere at point 4. The actual cycle is an “open” rather than “closed” cycle, as indicated. Every Brayton cycle can be characterized by two significant parameters: pressure ratio and firing temperature. The pressure ratio of the cycle is the pressure at point 2 (compressor discharge pressure) divided by the pressure at point 1 (compressor inlet pressure). In an ideal cycle, this pressure ratio is also equal to the pressure at point 3 divided by the pressure at point 4. However, in an actual cycle there is some slight pressure loss in the combustion system and, hence, the pressure at point 3 is slightly less than at point 2 (K.A.B.Pathirathna, 2013).
2.3. Gas turbine unit

The gas turbine unit consists of a 17–stage axial–flow compressor and a 3–stage power turbine. Each section, compressor rotor and turbine rotor, are assembled separately and then joined together. Through–bolts connect the compressor rotor wheels to the forward and after stub shafts. The turbine rotor also utilizes through–bolt construction with spacer wheels between the first– and second–stage and the second– and third–stage wheels. The assembled rotor is a three–bearing design utilizing pressure–feed elliptical and tilt–pad journal bearings. The three–bearing design assures that rotor–critical speeds are above the operating speed and allows for optimum turbine bucket/turbine shell clearances (Khor Al Zubair, 2005).

2.4. The effect of Inlet Temperature on Electricity production

Since the gas turbine is an air-breathing engine, its performance is changing by anything that affects the density and/or mass flow of the air intake to the compressor. Ambient weather conditions are the most obvious changes from the reference conditions of 15oC and 1.013 bars.

3. ANALYSES PROCEDURE

The gas turbine units have been analyzed in all stations (Erbil, Duhok and chamchamal). Those stations are working in similar geographic and climate conditions. However, there are slightly differences in the inlet ambient temperature. The data are collected for one year operation 365 working days in each station. Those data were recorded on June 2012 to June 2013. The power plant in each region consists of a gas turbine type MS9001 with rated capacity of 500 MW, each station consists of four units, and each unit with rated capacity of 125 MW electricity production, the output changes depending on the inlet temperature of the gas turbine.

4. RESULTS AND DISCUSSIONS

The result shows the variation of average inlet temperature on electricity production (power output) as shown figures below.

Figures 3, 4 and 5, are Illustrate the effect of variation of average inlet temperature on the power output for three stations (Erbil, Duhok and chamchamal). The highest electricity productions were found on January. While, the lowest electricity production were found on July. The highest of power output
recorded when the lower temperature in winter with increase in the power output up to 3.5 % above the standard conditions. Meanwhile, the losses in power output recorded up to 21.6 % below the standard conditions. For example in Erbil station In July when the average inlet temperature is around 45 °C the electricity production is around 95 MW it means that it is losses 30MW in each unit of stations. Also in figure 3 when the average inlet temperature in March around 15 °C the power output was 125 MW. While when the average inlet temperature reaches 44 °C the power output was 97 MW. So that the average power output of the plant decreases by 0.96 % for each 1 °C increase in inlet temperature in Erbil station and in Duhok 0.72 % and chamchamal 1.05 %. Finally overall in three cites the average power output of the plant decreases by 0.91 % for each 1 °C increase in inlet temperature.

Figure 6 shows the monthly average temperature for each of the power plant station (PPT). Gas turbines annual electricity production has been analyzed. Shows the variation of average temperature among the cities (Erbil, Duhok and chamchamal). While, figure 7 shows the variation of electricity production in among three cities. The highest losses recorded in Erbil stations.

Figure 8 and 9 shows a verification study for our result with the result of (Hasan and Suleyman ,2006).the figures showed good agreement between the results. This mean that our case study is validated and the behavior of the stations operation are correct.

Figure 3: Electric power generation variation with monthly averaged ambient temperature in Erbil power plant
Figure 4: Electric power generation variations with monthly averaged ambient temperature in Duhok power plant.

Figure 5: Electric power generation variations with monthly averaged ambient temperature in chamchamal power plant

Figure 6: Monthly average temperature distributions of the three regions.
Figure 7: Electricity productions with average inlet temperature for the three power plants

Figure 8: Comparison monthly averaged temperature distributions between Iraq and Turkey.

Figure 9: Comparison monthly averaged Electricity production between Iraq and Turkey.
5. CONCLUSIONS

In this study, a Comprehensive study analysis was conducted. The effect of average inlet temperature on the electric power production was analyzed for three stations. Electricity production decreases when the inlet temperature increases more than 15 °C in all stations. While the power production decreases up to 21.6% according to the standard condition of power output in each unit of stations. Also electricity production increases up to 3.5 % when inlet air temperature is less than 15 °C. Overall in three stations the average power output of the plant decreases by 0.91 % for each 1 °C up in inlet temperature.

6. REFERENCES

Alhazmy M. M. and Najjar Y.S.H. (2004), Augmentation of gas turbine performance using air coolers. Applied Thermal Engineering Volum 24 ; pp 415–429.

Amir Abbas Zadpoor, Ali Hamedani Golshan, (2006) Performance improvement of a gas turbine cycle by using a desiccant based evaporative cooling system, Energy 31 2652–2664

Chaker M., C.B. Meher-Homji, T. Mee, A. Nicholson, (2003) Inlet fogging of gas turbine engines detailed climatic analysis of gas turbine evaporation cooling potential in the USA, Journal of Engineering for Gas Turbine and Power 125 300–309.

Frank J. Brooks, (2007) GE Gas Turbine Performance Characteristics, GE Power Systems, Schenectady, NY.

Gareta R., L.M. Romeo, A. Gil. 2001The effect of inlet air cooling system in combined cycle performance, POWER-GEN 2001, Bruselos,

Hasan H. Erdem *, Suleyman H. Sevilgen (2006) Case study: Effect of ambient temperature on the electricity production and fuel consumption of a simple cycle gas turbine in Turkey. Applied Thermal Engineering 26 (2006) 320–326.

K.A.B.Pathiratna, (2013) gas turbine thermodynamic and performance analysis method available catalog data. Msc thesis,University of Gavle

Kakaras, E., (2006) Inlet Air Cooling Methods for Gas Turbine Based Power Plant, ASME vol.128, ,pp. 312-317.

Khor Al Zubair, (2005). MS9001E GAS TURBINE OPERATIONS TRAINING, Iraq

Loud R.L., A.A. Slaterpryce, (1993). Gas Turbine Inlet Air Treatment,37th GE Turbine State of the Art Technology Seminar

Mohanty B. and Paloso J. (1997) Enhancing gas turbine performance by intake air cooling using an absorption chiller. Heat Recovery Syst. CHP J. 15 (1) 41–50.