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Performance Evaluation Of Gas Turbine By Reducing The Inlet Air Temperature

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ABSTRACT: Performance of a gas turbine is mainly depends on the inlet air temperature. The power output of a gas turbine depends on the mass flow rate of air. Now days the atmosphere temperature is hot, so the air is less density, the mass flow rate will reduce and automatically the power output will reduce. A reduce of 1°C temperature of inlet air increases the power output by approximately 0.7MW. To reduce the inlet air temperature by using the various techniques evaporative coolers, vapor compression chillers, and absorption chillers. In this paper the performance of 100MW model capacity gas turbine is compared by reducing the inlet air temperature from 35°C to 25°C. The results are taken from the GT PRO software and this software is mainly used for power plant design.

Keywords : Gas turbine, evaporative coolers, vapor compression chillers, absorption chiller

1 INTRODUCTION

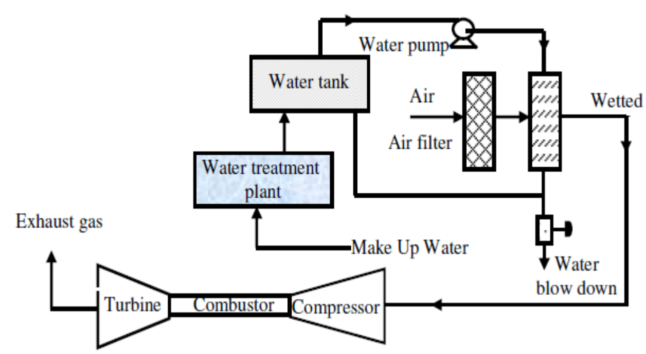
Gas turbines are working under isochoric process and constant shaft speed. The inlet air will be taken from the atmosphere directly and the performance of gas turbine is based the atmosphere air conditions. During the summer seasons, the gas turbine power output will be reduced due to increase in inlet atmospheric air temperature. Gas turbines are designed based on ISO conditions (15°C and 60% RH). The performance of gas turbine will be increased by the air cooling system during hot conditions. The inlet air temperature rises, the volumetric flow rate of air to the compressor will be reduced due less density. Hence the best way to get maximum output of gas turbine is to reduce the inlet air temperature by using the air cooling systems. This paper introduces the performance evaluation of gas turbine (100MW model) by reducing the inlet air temperature from 35°C to 25°C and also the various air cooling system are used to improve the performance of the gas turbine. The air cooling system describes in detail the evaporative cooler, vapor compression chiller and absorption chiller.

2 INLET AIR COOLONG METHODS

2.1 EVAPORATIVE COOLER

Evaporative coolers are used to reduce the air temperature and increase the relative humidity. In this system the density of combustion air will be increased because of reduction in the air temperature, thereby increasing the power output. However the fuel consumption of the gas turbine will be increased due to increase in density and increase in relative humidity.

FIG 1. EVAPORATIVE AIR COOLING (RAHMAN, 2011).



The evaporative coolers are mainly two types, spray type and pad type. This system mainly consists of water pump, headers, pipes, drain, valves and fittings. The water will be pumped from the water tank through the strainers and valves. The pumped water will be passed to the headers, from the headers water will be sprayed through the nozzles. The water will be sprayed from the top of the chamber and air will cross the chamber in perpendicular direction and water drops reduces the air temperature and increases the relative humidity. The drain water will be collected at bottom of the chamber and again reused for the cooling purpose through the filters. The cooling water should be pretreated water, otherwise will causes the filters and strainers need more maintenance. Due to evaporation of water in this process, makeup water should be provided and necessary blowdown also required.

2.2 VAPOR COMPRESSION CHILLER

Vapor compression chiller is required more power consumption and more effective method for cooling the inlet air then the evaporative coolers method. In this system refrigerant is used, the air temperature will be reduced to near the wet bulb temperature. The main principle is the latent heat of vaporization is utilized for absorbing the heat from low temperature space and transfers it to surrounding so that the space is maintained at a temperature lower than that of surrounding. This refrigeration system has the following components,

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Compressor: The main function of the compressor is to increase the pressure and temperature above atmospheric. The compressor used here is of reciprocating type.

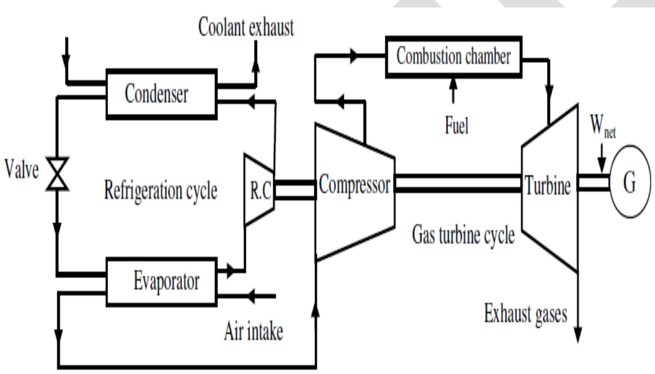
Condenser: The condenser is used to cool the vapour refrigerant and the vapour state will be converted into liquid by using water cooling or air cooling system.

Expansion Valve: The valve is used to reduce the temperature and pressure of the liquid refrigerant.

Evaporator: Evaporator causes the cooling effect in the refrigeration space by absorbing the heat from the space. Normally it made up of copper coils.

The high pressure vapour refrigerant from the condenser enters the expansion or throttle valve where it expands to the required pressure. During expansion pressure is reduced and the vapour becomes partially converted to liquid and produces cooling effect. A mixture of low temperature vapour and liquid from expansion valve is then enters the evaporator and absorbs heat from the space to be refrigerated. Because of this, liquid becomes vapour and this vapour enters the compressor. There it is compressed, thus the pressure goes up. The high pressure vapour enters the condenser and looses its latent and becomes liquid. The liquid refrigerant is stored in a receiver and supplied to the expansion valve, and the cycle continues.

FIG 2. VAPOR COMPRESSION CHILLER (LUCIA ET AL., 1994).



This system consumes more power to drive compressor and pumps. The initial cost of the machine is high and slightly maintenance cost also high.

2.3 VAPOR ABSORPTION CHILLER

In recent years Vapor absorption chiller becomes more interest due to its potential use as part of power saving plant. Also it uses more environment friendly refrigerants than current vapour compression chiller. This used heat energy instead of mechanical energy as in vapour compression chiller. This system differs from vapour compression system in such a way that the compressor is replaced by ana absorber and generator. The absorber absorbs the refrigerant and mixes it with the weak solution to produce strong solution. The function of generator is to heat the strong solution to form vapour of the refrigerant. There are two types of vapour absorption chiller depending on the refrigerant and absorbent.

Ammonia - Water system

Lithium Bromide – Water system

The vapor absorption chiller consists of the following components,

Generator: The generator is used to receive the strong solution of aqua-ammonia and heated by using the available heat source. During heating, strong ammonia and weak ammonia are separated.

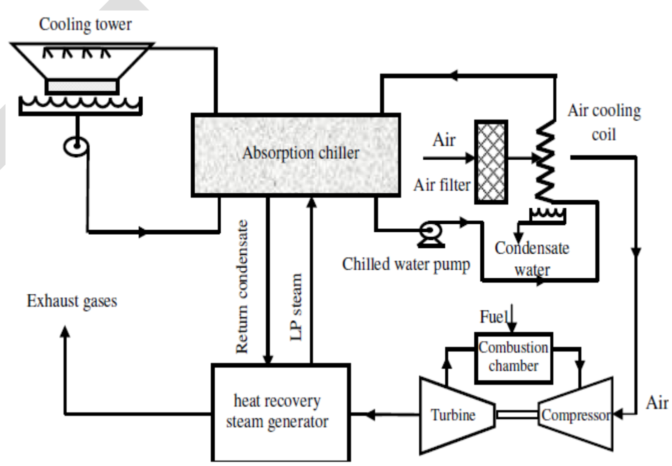
Condenser: The condenser is used to cool the vapour ammonia and the vapour state will be converted into liquid ammonia by using water cooling or air cooling system.

Expansion valve: The valve is used to reduce the temperature and pressure of the liquid ammonia.

Evaporator: Evaporator causes the cooling effect in the refrigeration space by absorbing the heat from the space. Normally it made up of copper coils.

Absorber: The absorber is used to receive and mix the weak ammonia from the generator and ammonia vapor from the evaporator to produce the strong aqua ammonia solution.

FIG 3. VAPOR ABSORPTION CHILLER (KAKARAS ET AL., 2004)



The high pressure vapour refrigerant from the condenser enters the expansion or throttle valve where it expands to the required pressure. During expansion pressure is reduced and the vapour becomes partially converted to liquid and produces cooling effect. A mixture of low temperature vapour and liquid from expansion valve is then enters the evaporator and absorbs heat from the space to be refrigerated. Then the vapour reaches the absorber where it is readily absorbed in a low temperature absorbing medium. So, it mixes with the weak solution, thus the solution now becomes strong. Some heat being rejected during the process. This strong solution is pumped to the high pressure and passes through heat exchanger. Here, it takes some heat from the weak solution which is throttled

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and returning back to the absorber. Generator heats the strong solution, there by forming ammonia vapour. During heating, some water may also be vaporized. The pure ammonia vapour enters the condenser and cooling water is passed through the condenser and the cycle continues.

3 GT PRO SIMULATION FOR 100MW GAS TURBINE

The GT Pro software is used to generate the heat and mass balance diagram and all the system design. A typical gas turbine was used for evaluation of 35°C and 25°C inlet air temperature in GT pro software. The standard 100MW model of gas turbine has been taken and the design conditions are 15°Cand 60% RH. The 100MW model gas turbine has one compressor, one turbine, one regenerator, one compressor intercooler, and one combustor.

3.1 INLET AIR TEMPERATURE 35°C

The air inlet temperature of gas turbine is 35°C for that mass flow rate enters into the compressor is 671T/H with the atmospheric pressure. This air is compressed in the compressor and the pressure is increased and passed to the combustor for making complete combustion with methane gas. The methane gas will be compressed from 10 bar to 56.84 bar and the temperature of the methane gas also increased from 25 °C to 149.1°C. In the combustion chamber both compressed air and methane gas are making the complete combustion and produces the exhaust gas with high temperature and pressure. This exhaust gas will enter in the turbine and the turbine blades are start to rotate due to high heat energy converted to kinetic energy. So that the high temperature and pressure of exhaust gas in the turbine will reduces due to increases in the specific volume. The exhaust gas pressure and temperature are 1.001 bar and 431.5°C. The turbine is connected with the generator, when the turbine shaft is rotating an emf will produce in the generator due to conversion of energy to kinetic energy. For that 100MW model gas turbine, the inlet air temperature of 35°C condition will produce the gross power output of the turbine as 91.384MW.

3.2 INLET AIR TEMPERATURE 25°C

The air inlet temperature of gas turbine is 25°C for that mass flow rate enters into the compressor is 703.1T/H with the atmospheric pressure. This air is compressed in the compressor and the pressure is increased and passed to the combustor for making complete combustion with methane gas. The methane gas will be compressed from 10 bar to 56.84 bar and the temperature of the methane gas also increased from 25 °C to 149.1°C. In the combustion chamber both compressed air and methane gas are making the complete combustion and produces the exhaust gas with high temperature and pressure. This exhaust gas will enter in the turbine and the turbine blades are start to rotate due to high heat energy converted to kinetic energy. So that the high temperature and pressure of exhaust gas in the turbine will reduces due to increases in the specific volume. The exhaust gas pressure and temperature are 1.001 bar and 423.5°C. The turbine is connected with the generator, when the turbine shaft is rotating an emf will produce in the generator due to conversion of energy to kinetic energy. For that 100MW model gas turbine, the inlet air temperature of 25°C condition will produce the gross power output of the turbine as 98.486MW.

FIG 4. GAS TURBINE HMBD FOR INLET AIR TEMPERATURE 35°C FROM GR PRO

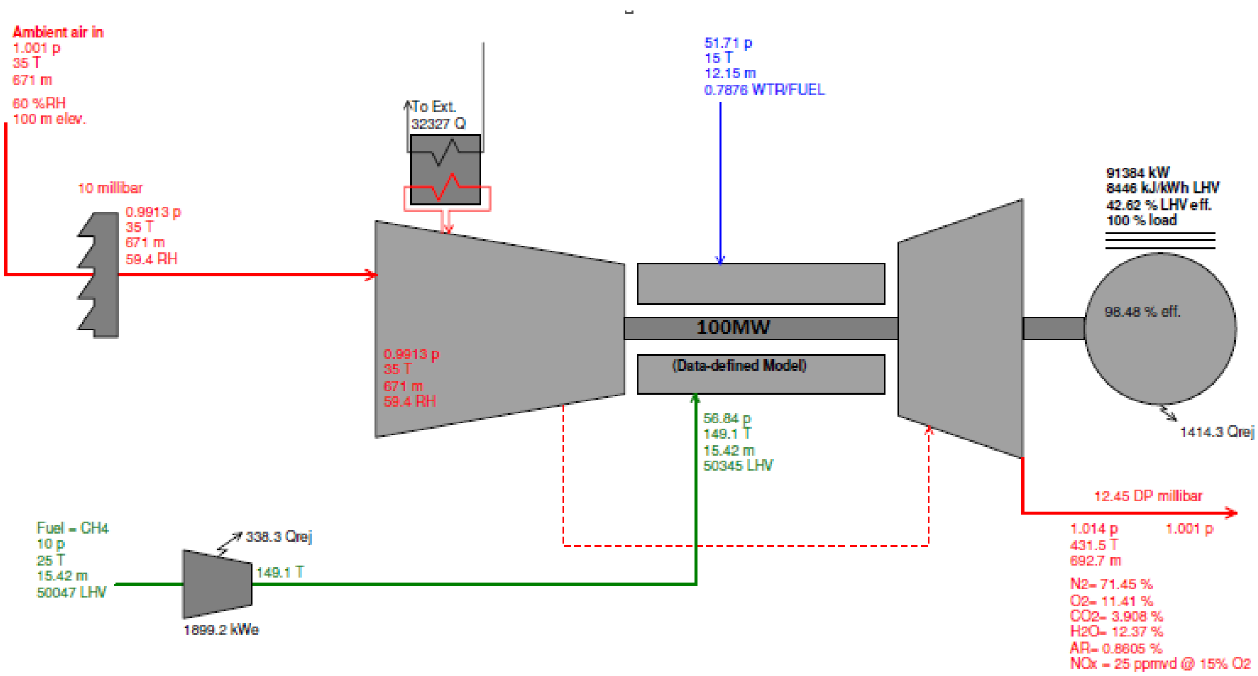
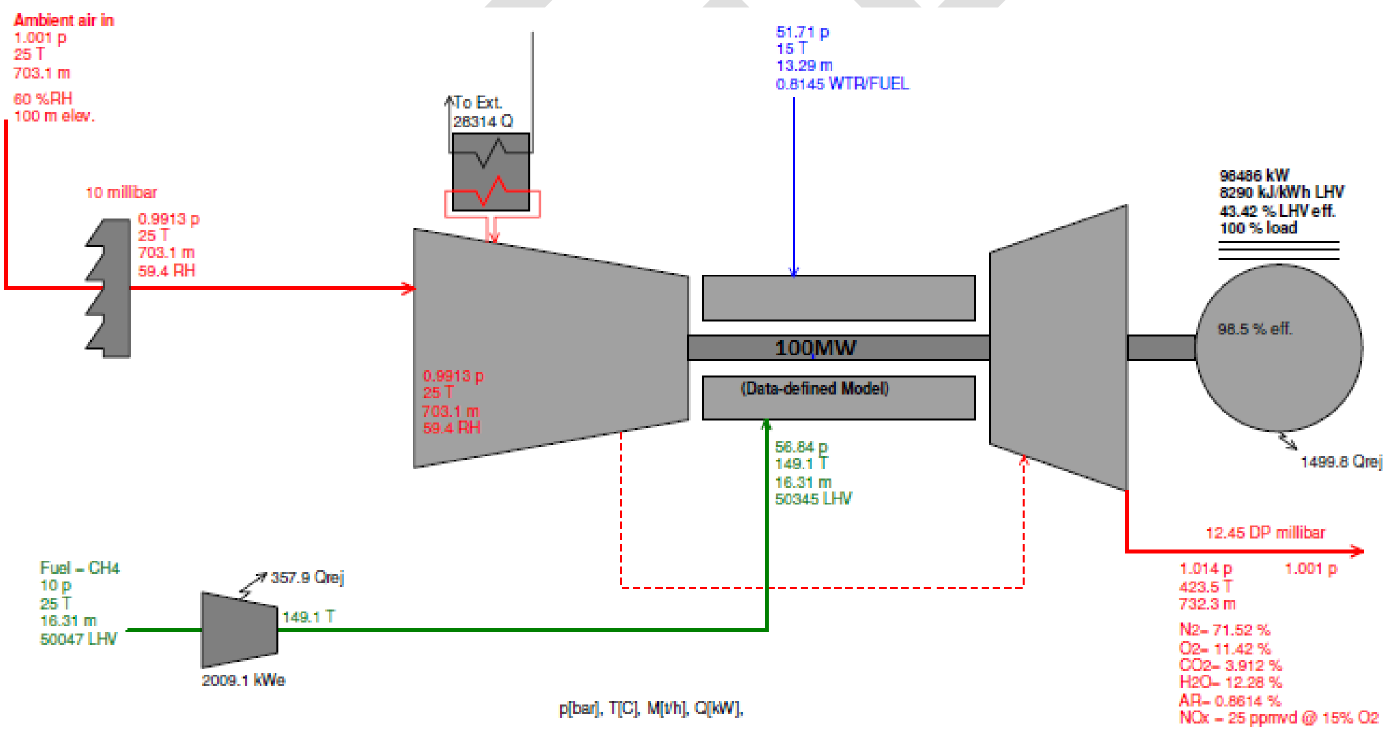


FIG 5. GAS TURBINE HMBD FOR INLET AIR TEMPERATURE 25°C FROM GR PRO



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4 RESULT AND CONCULSION

TABLE I GAS TURBINE PERFORMANCE FOR 35°C AND 25°C

AIR TEMEPERATURE °C	MASS FLOW RATE T/H	COMPRESSOR POWER KW	FUEL- CH4 MASS FLOW RATE T/H	GT HEAT RATE KJ/KWH	GT EFFICIENCY %	GT POWER MW
35	671	32327	15.42	8446	42.62	91.384
25	703.1	28314	16.31	8290	43.42	98.486

Based on the GT PRO result, the performance of a gas turbine is mainly depends on the inlet air temperature. The temperature of air reduces, the mass flow rate of air will increase due to increase in density and power output will increases. A reduce of 1°C temperature of inlet air increases the power output by approximately 0.7MW.

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REFERENCES

[1] Thamir K. Ibrahim, M. M. Rahman, “Improvement of gas turbine performance based on inlet air cooling systems: A technical review”, IJPS, 2011, Vol. 6(4), pp. 620-627. (*references*)

[2] Ait-Ali MA , “Optimum power boosting of gas turbine cycles with compressor inlet air refrigeration” ASME., 1997, 119: 124-130.

[3] Boonnasaa S, Namprakaia P, Muangnapoh T, “Performance improvement of the combined cycle power plant by intake air cooling using an absorption chiller” Ener.,2006, 31: 2036-2046.

[4] Hosseini R, Beshkani A, Soltani M, “Performance improvement of gas turbines of Fars (Iran) combined cycle power plant by intake air cooling using a media evaporative cooler” Ener. Conver. Manage., 2007, 48: 1055-1064.

[5] Kakaras E, Doukelis A, Karellas S, “Compressor intake-air cooling in gas turbine plants. Energy”, 2004, 29: 2347-2358.

[6] Kakaras E, Doukelis A, Prelipceanu A, Karellas S, “Inlet air cooling methods for gas turbine based power plants” Trans. ASME., 2006, 128: 312-317.

[7] Polyzakis AL, Koroneos C, Xydis G, “Optimum gas turbine cycle for combined cycle power plant” Ener. Conver. Manage., 2008, 49: 551- 563.

[8] Sadrameli SM, Goswami DY, “ Optimum operating conditions for a combined power and cooling thermodynamic cycle”, Appl. Ener*., 2007,* 84: 254-265.

[9] Zadpoor AA, Golshan AH, “Performance improvement of a gas turbine cycle by using a desiccant-based evaporative cooling system” Ener., 2006, 31: 2652-2664.

[10] Mohanty B, Paloso J, : Enhancing gas turbine performance by intake air cooling using an absorption chiller” Heat Recovery Syst CHPJ 1995; 15(1):41–50.