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Improvement in gas turbine efficiency to meet the summer demand

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Abstract
A gas turbine is a machine with internal combustion like diesel engine today it is considered to be a critical part of the future heat and power generation system as well as several parts of the transportation sector but The basic gas turbine has low efficiency. The degradation of the gas turbine output power with the rise in ambient air temperature posses a serious problem during the summer when demand for the turbine o/p is at its highest additionally gas turbine loss capacity over their life time due to this degradation this factor is of the major concern for the researches several methods are suggested for improving the cycle performance in previous studies all of which offer improved performance and increased specific output compared to a simple gas turbine Cooling of intake air is one of the most popular method of the improving the efficiency in the present paper the result of the integration of the alternative regenerator arrangement with different popular cooling method for compressor intake air are presented and the improvements that can be achieved are discussed.

Keywords: cycle performance, Regenerator, system inject gas turbine cycle (S.T.I.G.) regenerative gas turbine (E.R.G.T.) humid air turbine

Introduction

One conventional method to improve the efficiency of the existing gas turbine plant is the use of regeneration in the gas turbine exhaust. The regenerator is the large air/air heat exchanger that heat ups the compressed air before it enters the combustion chamber. Heat from the exhaust gases will heat up the compressed air after which the air is directed towards the combustion chamber. The heat exchanger consists of large no of finned pipes. The compressed air flow through the pipes and the exhaust gases around the pipes. The exchanger is designed to absorb expansion and shrinkage during start up and stop The connecting pipe between exchanger and the gas turbine is designed to avoid pressure losses as much as possible. The output of the gas turbine depends upon the mass flow rate of the air through turbine The performance of the gas turbine varies significantly with ambient temperature of the atmosphere. Previous studies shows that the eff. Of the gas turbine improves to 60 % mark to the 32-40% when converted to the combined steam and gas turbine cycle the density of the air decreases with the increase of its temp resulting in the reduced mass flow rate through the compressor and the turbine there by causing the reduced in the turbine output Usually this decrease in the output happens when power is needed the most. This degradation in output can be avoided by cooling the inlet air to the compressor to a temp. Lower then the atmosphere temp It is seen that for every 10 k rise in the ambient air temp there 5% reduction in Hence the inlet air cooling is one of the most important parameter to entertain. This may be achieved by following different way like evaporative cooling, cooling with the absorption cooling, system inject gas turbine cycle (S.T.I.G) regenerative gas turbine (E.R.G.T.) humid air turbine (hat) evaporative cooling of pre-

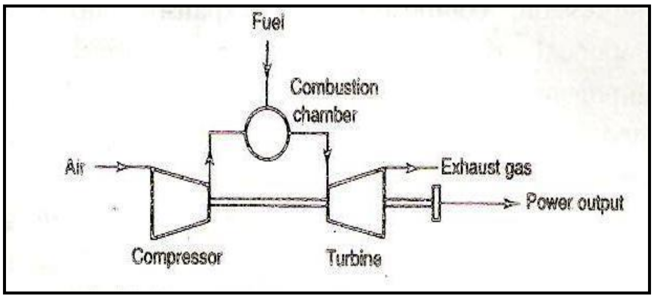

Fig 1

Compressed air etc, It is claimed that only an absorption chillers used to cool intake air to 15"c temp (I.S.O) can increase the power output of the gas turbine by 10.6%and combined cycle plant by around 6.24%annually Hence inlet air cooling not only improve the specific work o/p from a simple gas turbine cycle but also make the cycle performance independent of the ambient temp variations inlet air cooling has been recognized as one of the most cost effective means of increasing the turbine capacity the objective of this paper is to discuss the improvement that can be achieve by integrating different popular methods of inlet air cooling method with alternative regenerator arrangement.

Alternative regenerator arrangement

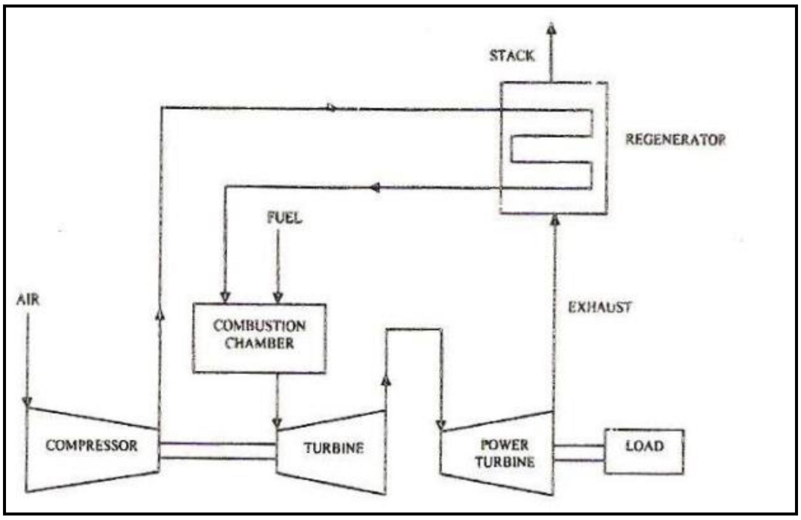

Fig 2: Simple re-generative cycle

The compressor discharge air is heated with hot combustion gases before entering the power turbine. This arrangement named as alternative regenerative the power turbine. This arrangement named as alternative regenerative configuration result greater efficiencies than conventional regenerative cycles operating

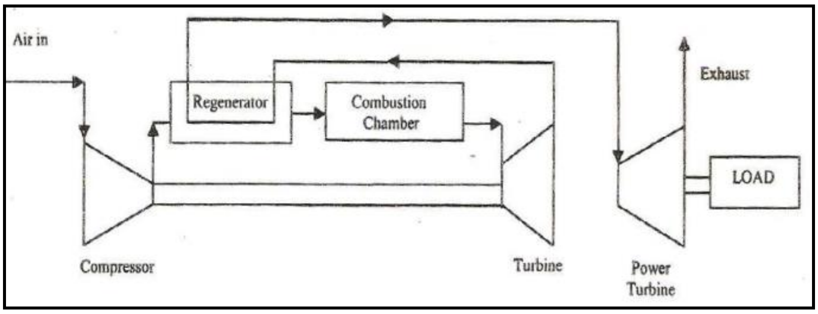

Fig 3: An alternative re-generation cycle

under the same conditions because air enters the combustor at higher temperature and hence heat addition in the combustor occur at a higher average temperature.

This high temperature of heat addition increases the gas turbine efficiency. In this way the maximum amount of work is extracted from the high enthalpy gas stream before any heat is recovered. A gas turbine cycle with a high pressure turbine and a power turbine is considered. If a heat exchanger is located between the two turbine the cycle efficiency can be substantially improved beyond that available from the conventional regeneration configuration. Although there is less work produce by that power turbine in the alternative regeneration scheme. The cycle efficiency improved and the lower specific work output can suitably compensated using different large sized engine component.

Compressor inlet air cooling

Out of the several performance enhancing options available for a gas turbine based cycle. Inlet air cooling is highly effective means of increasing the performance during hot ambient condition. the effect of ambient temperature on turbine output is diminished by cooling the air at its compressor intake. The gas turbine performance becomes consistent predictable figure shows the effect of ambient temperature on turbine output,

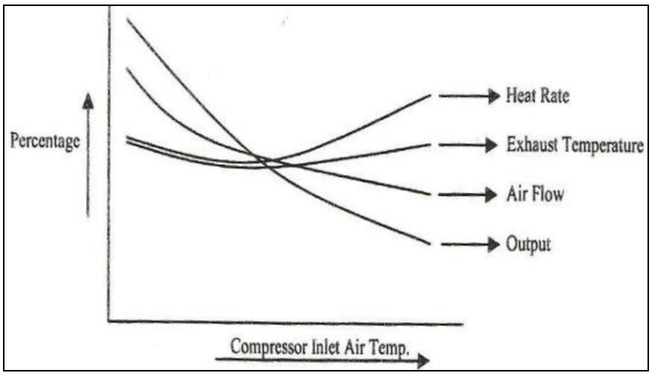

Fig 4: Effect of air temperature on gas turbine performance

heat rate, airflow and turbine exhaust temperature the total gain in combined cycle power output due to reduction of inlet air temperature is higher than a gas turbine running in simple cycle mode.

Types of Cooling System

Broadly there are two types of inlet air cooling system.

1) Evaporative cooling
2) Refrigerated cooling

1) Evaporative cooling

In evaporative cooling water is brought in contact with the incoming air. During evaporative water absorbs its latent heat of evaporation from the air and the air stream get cooled. The process cooled the inlet air to near WBT. Hence it is suitable for the drier climate. For reasons with high humidity, they provide minimal cooling due to the presence of the high moisture content in the ambient air limits its ability to absorb the additional moisture. Treated water required to prevent scales etc. This type of cooling is relatively in expansive to install. When foggers are used water is spread into the air stream through nozzles placed at cross section of the incoming air. Since the orifice these nozzles is only a few thousands of an inch, therefore treated water is obtain required to prevent clogging of nozzle opening. The size of the droplets depend upon the nozzles media require a large surface area to allow for sufficient contact time air and the water this may raise a concern for retrofits if sufficient space at the inlet duct is not available for media installation. The media imposes and additional pressure drop during colder ambient condition when cooling is not required

2) Refrigerating cooling

Refrigerated cooling can increase the gas turbine power output by 15-20% and efficiency by 1-2% the concept of inlet air cooling through refrigeration to boost the power output from the gas turbine. Depending on the duration of cooling required refrigerated cooling can be further classified into cooling with thermal energy storage and continuous cooling.

Thermal Energy Storage

When power increment is required for only few hours in a day, this method is utilized. in this system cold reserve is built during the non-peak hours, which is utilized during the non-peak hours to cool inlet air and increase turbine output. Size of the refrigeration system is considerably reduced in comparison to the other systems since the energy reserve is built for the longer time then when it is utilizes. Although some power is required for the chilled water system and auxiliaries almost the entire gain in the output during the peak hours is available as dispatch able power. A combination of the various cooling system may sometimes give better results. An economic evolution of the system optimization is required for the proper system selection. This application is found to be feasible in certain cases for the large turbines when the demand is such that cooling is required for the continuous period of time and yet the demand peaks only for the few hours a day.

Continuous Cooling

Continuous cooling is particularly effective when there is need for the power enhancement for more then 6 hours a day this type of cooling provides instantaneous cooling and direct refrigeration absorption and chillers, etc. Are different means of providing cooling the refrigerants is directly circulated through cooling coils placed in the filter housing? ammonia is preferred since it avoids the acid formation in combustion chamber. The optimum system is an ammonia system utilizing the screw compressor and evaporative condenser. A liquid overfeed is utilized to increase the heat transfer coefficient by 25 -30 % a gas fired compressor unit results in less power consumption then an electrically driven compressor. for a gas fired unit there is an increase in net power enhancement but the equipment cost is higher. gas driven compressor is recommended when saving in auxiliary power consumption is absolutely needed. If the refrigerants leaks it immediately flashes into vapour because of reduction in the pressure. The pumped refrigerant is stored in the low and high pressure receivers.

The use of the electrical chillers has been successfully applied to provide continuous cooling for the several installations. the power required for the electrical chillers is more then electrical refrigeration system however recent improvements in the efficiency have narrowed this differences. Absorption refrigeration using lithium bromide have been successfully applied for the cooling on many gas turbine installation for the many years. This system can cool the inlet air to about some temperature limit and heat source either gas or steam is needed to drive the auxiliaries like pumps and fans etc.

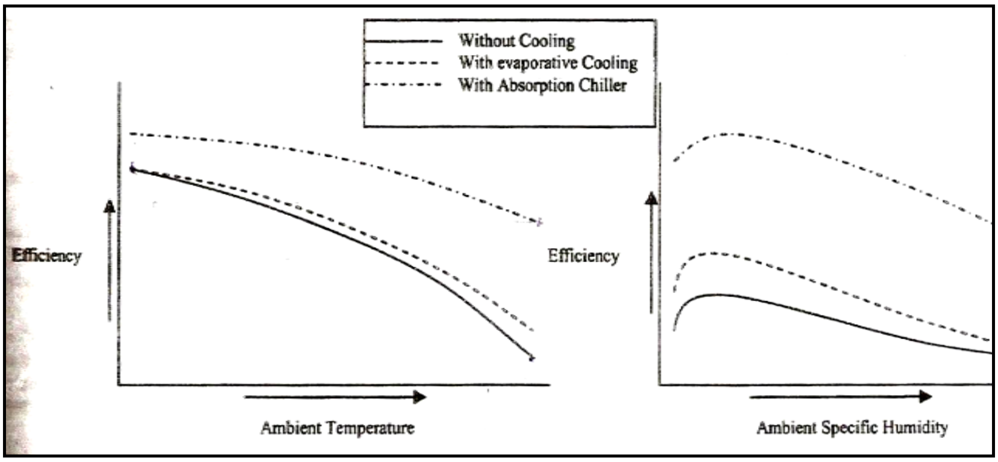

Fig 5: Efficiency v/s temperature and also with ambient specific humidity

The variation in efficiency as a function of ambient temperature for a simple gas turbine cycle for relative humidity value of 60% output of the gas turbine decreases by around 10% with the ambient temp condition rise from the iso condition to the 30c Relative humidity of the ambient air affects the effectiveness of the evaporative cooling performance With increase in ambient air humidity the amount of evaporator in the cooling reduced which in turn reduces the effectiveness of the evaporative cooling. Absorption chillers utilizes the exhaust energy to produce cooling effect which increases the efficiency of the gas turbine, Cooling by the absorption chillier is not affected by the ambient air humidity so absorption chillier is equally efficient in humid weather where evaporative coolers prove to be inefficient.

Results and Discussions

Cooling of the inlet air improves the power output and efficiency of the gas turbine. It is seen for every 10 k

increase in the temp. There is reduction in the output by 5%. It has been observed that cooling system results efficiency of 37.23% for evaporative cooling and 37.73 % for absorption refrigeration cooling in comparison to 36.62% for a simple cycle without cooling obviously absorption refrigeration cooling improves efficiency fairly high i.e. 3.03% in comparison to 1.67% for evaporative cooling Now the conventional regeneration improves the cycle efficiency from 42.7 % at very high optimum pressure ratio of 37 for the simple cycle assuming no regeneration pressure drop to 43% at an optimum pressure ratio of the 8 only for the ideal class where there is no pressure drop across the regenerator, the cycle efficiency becomes 45.9% With nominal optimum pressure of 16 But practical gas turbine engines having regenerator certainly undergoes some pressure drop through regenerator and even for the moderate pressure drop, conventional regenerator performs inferior efficiency below 40% even in comparison to the simple cycle efficiency 42.7% for such practical case.

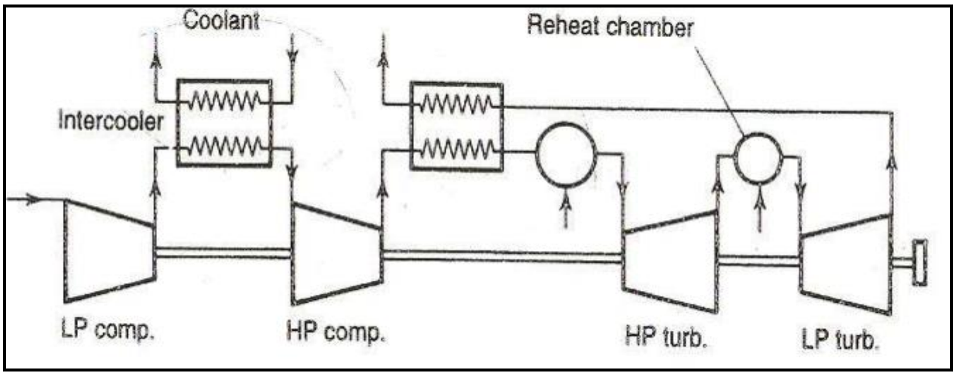

Fig 6: Integrated plant with inter, heat exchange, reheat.

This makes conventional regenerative system unsuitable for the practical gas turbine engines. On the other hand the alternative regenerative cycle shows least effect of the pressure drop i.e. for the practical cases, on the cycle efficiency as compared to both simple cycle and conventional regeneration system for the nominal pressure ratio of 16 even with moderate pressure drop of 2 psi it gives best performance efficiency 44.6% then other two Using the alternative regenerative configuration shows the efficiency of 50% at a nominal pressure ratio of 22 which is easily achievable and within the range of the operation with modern design of the compressor available.

Conclusion

In the present study two different cooling methods for the inlet air cooling in gas turbine based power plants i.e. evaporative cooling and refrigeration cooling have been examined. It was found that power output is obtained by absorption intake air cooling is more as compared to that by evaporative cooling method. hence if increase in power output and efficiency is criterion for the selection refrigerated cooling is selected which improves the cycle efficiency by using cooling system from 36.62% to 37.73%. Further this system is integrated with alternative regenerative cooling system this configuration increases the efficiency of a simple cycle to 44.6% mark from 42.7%for the practical range of the pressure ratio and for practical moderate practical moderate pressure drop against the regenerator. Hence it is concluded that when a simple cycle is integrated with refrigerated cooling and an alternative regenerator arrangement the normal efficiency 36.62% may be improved to 39.41% for practical cases of regenerator pressure drop against 40.56% considering an ideal case with normal pressure ratio of 22 which is easily attainable.

References

1. Upadhyay P, Bajpai SK, Manoj Modi. "effect of integration of alternative regenerator with cooling of intake air on the performance of gas turbine "IJME, 09(2):63-67.
2. PK. Nag By Power plant engineering, Stem power plant, TMH india
3. COGEN H. Chapter-Introduction-50 Year gas turbine theory, 5th Edition, Published by pearson education, ipe indiahttp//www.scmiiraq.comimages49-gasturbine inlet.
4. GANESHAN V. A text book of gas turbine, TMH india
5. A text book of steam and gas turbine power plant engineering by R. YADAV
6. Ganapathy T, Alagumurthi N, Gakkhar RP, Murugesan K. "Exergy Analysis of Operating Lignite Fired Thermal Power," Journal of Engineering Science and Technology Review. 2009; 2(1):123130
7. Dincer. MA Rosen. "Effect of Varying Dead-State Properties on Energy and Exergy Analyses of Thermal Systems," International Journal of Thermal Sciences. 2004; 43(3):121-133.
8. Dincer MA. Rosen and N. L. Minh, "Efficiency Analysis of a Cogeneration and District Energy System," Applied Thermal Engineering. 2005; 25(1):147-159.