International Journal of Engineering Research and Reviews **ISSN 2348-697X (Online)**
Vol. 4, Issue 2, pp: (20-32), Month: April - June 2016, Available at: www.researchpublish.com

Numerical Analysis for the Prediction on the Effect of Heat Transfer Characteristics of Combined Cycle Gas Turbine Using Inter Cooler

[1]SARATH RAJ , [2]ARUN RAJ, [3]ARUN RAJ C.S, [4]AKHIL K SUNIL
[5]ANOOP.U, [6]SAJIN.S

[1]Assistant Professor, Department of Mechanical Engineering, Sree Narayana Institute of Technology, Adoor, Kerala, India
[2,3,4,5,6] Final year B Tech students Department of Mechanical Engineering, Sree Narayana Institute of Technology, Adoor, Kerala, India

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Abstract: **The gas turbine cycle has various uses in the present scenario. The gas turbines are mainly used for power generation in power plants. The gas turbine cycle is based on Brayton cycle. In the present work the parametric study of a gas turbine cycle model power plant with use of intercooler is proposed. The thermal efficiency, specific fuel consumption and net power output are simulating with respect to the temperature limits and compressor pressure ratio for a typical set of operating conditions. Simple gas turbine cycle calculations with realistic parameters are made and it confirms that increasing the turbine inlet temperature no longer means an increase in cycle efficiency, but increases the work done. The analytical study is done to investigate the performance improvement of gas turbine by the use of intercooler. The analytical formula for specific work and thermal efficiency are derived and analysed. The simulation results shows that decreasing the ambient temperature and increasing the pressure ratio can improve the performance of the intercooled gas turbine cycle further. The increase in ambient temperature cause decrease thermal efficiency, but the increase in turbine inlet temperature increases the thermal efficiency.**

Keywords: **Gas Turbine; Breton Cycle; Intercooler; Thermal Efficiency; Specific Fuel Consumption; Compressor.**

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1. INTRODUCTION

Combined cycle power generation is a method of generating electric power that combines gas turbine power generation with steam turbine power generation. By employing a 1,100°C class gas turbine in the high-temperature section and by effectively recycling the exhaust energy of this section in the steam system, the thermal efficiency can be boosted to 43%. Furthermore, several small-capacity individual units are combined to configure a large-capacity power generation facility and start up and shut down operations can be easily tailored to the fluctuation in demand. For this reason, by adjusting the number of operating units under middle and low outputs, the facility can be run at all times with the same high efficiency as with the rated outputs. This, together with other features, makes combined cycle power generation an excellent system in terms of mobility and thermal operating efficiency. A typical simple-cycle gas turbine will convert 30% to 40% of the fuel input into shaft output. All but 1% to 2% of the remainder is in the form of exhaust heat. The combined cycle is generally defined as one or more gas turbines with heat-recovery steam generators in the exhaust, producing steam for a steam turbine generator, heat-to-process, or a combination the above. The figure below shows a combined cycle in its simplest form. High utilization of the fuel input to the gas turbine can be achieved with some of the more complex heat-recovery cycles, involving multiple-pressure boilers, extraction or topping steam turbines, and avoidance of steam flow to a condenser to preserve the latent heat content. Attaining more than 80% utilization of the fuel input by a combination of electrical power generation and process heat is not unusual. Combined cycles producing only electrical power are in the 50% to 60% thermal efficiency range using the more advanced gas turbines.

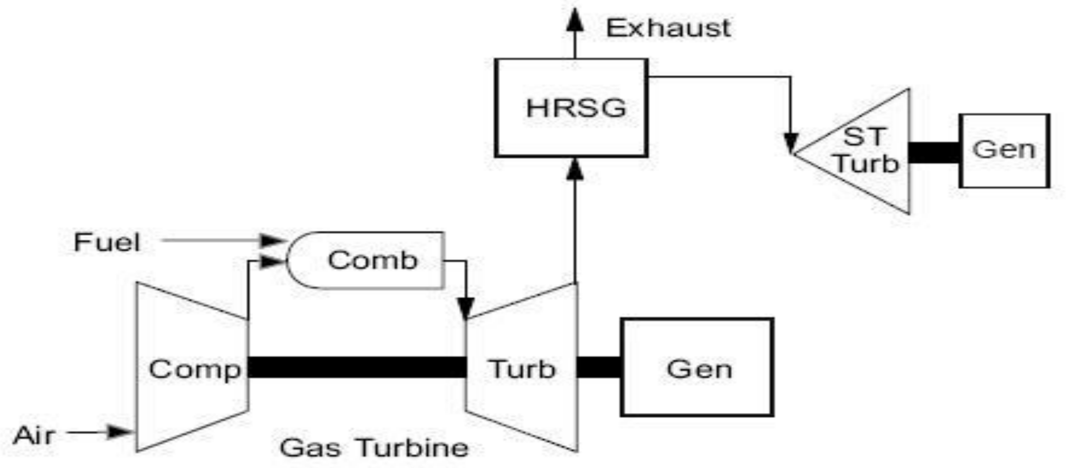

Figure1.1: Combined Cycle Layout

2. GAS TURBINE BASICS

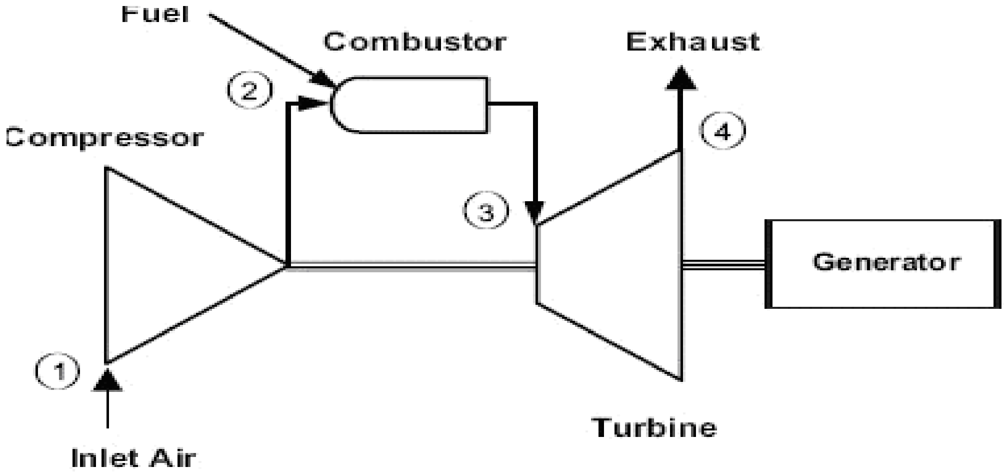

Figure.2.1: Simple cycle single shaft gas turbine

The gas turbine works on the basic Brayton cycle. 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. 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. Thus, by the time the combustion mixture leaves the combustion system and enters the turbine at point 3, it is at a mixed average temperature. In the turbine section of the gas turbine, the energy of the hot gases is converted into work. This conversion actually takes place in two steps. In the nozzle section of the turbine, the hot gases are expanded and a portion of the thermal energy is converted into kinetic energy. 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 developed by the turbine is 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.

2.1 TURBINE:

The turbine in all modern GT, regardless of the type of compressor used, is of axial flow design. The turbine extracts kinetic energy from the expanding gases as the gases come from the burner, converting this energy into shaft horsepower to drive the compressor and the engine accessory. Nearly three fourths of all energy available from the product of combustion is needed to drive the compressors. The turbine wheel is one of the most highly stressed parts in the engine. The inlet temperature to the turbine is limited at 1124°C. To withstand this temperature, the turbine blades are made of specially alloyed steel containing chromium, molybdenum and vanadium. The blades should also withstand severe centrifugal loads imposed by high rotational speeds of 3000 rpm. The blades are attached to the disk by means of a "fin tree" design to allow for different rates of expansion between the disk and the blade while still holding the blade firmly against centrifugal loads.

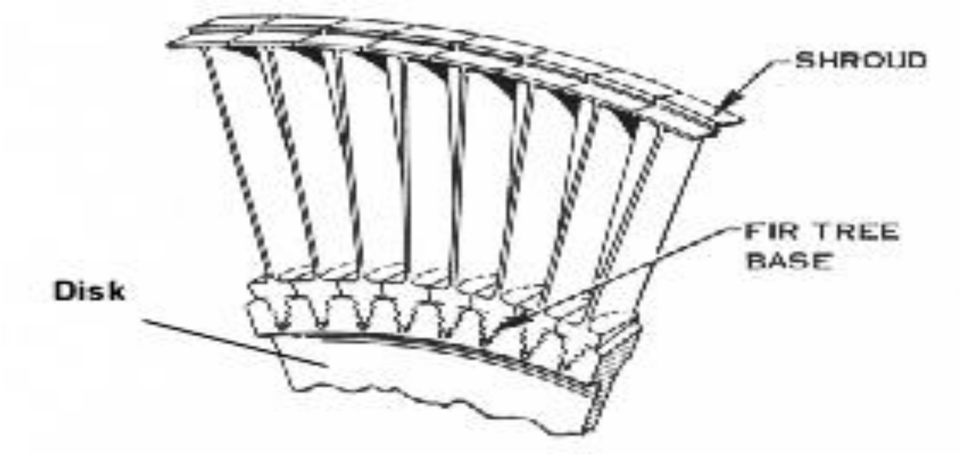

Figure.2.2: Turbine vanes

The blade is shrouded at the tip. The shrouded blades form a band around the perimeter of the turbine which serves to reduce blade vibrations. The shrouds improve the airflow characteristics and increase the efficiency of the turbine. The shrouds also serve to cut down gas leakage around the tips of the turbine blades.

2.1.1 CLASSIFICATION OF GAS TURBINE:

Gas turbines are divided in to two types .They are

1. Open cycle gas turbine

2. Closed cycle gas turbine

2.2 OPEN CYCLE GAS TURBINE:

In the open cycle gas turbine air is drawn in to the compressor from the atmosphere. The compressed air is heated by using the burner; the air must be burned directly. In the combustion chamber the fuel in the air inside maintains at constant pressure. From the combustion chamber the high pressure hot gases drive the turbine. The power must be developed when the turbine shaft rotates. There is no self-starting in the Gas turbines. The starting motor drives the compressor till the fuel is injected in the combustion chamber. If the turbine frights gain speed then the starting motor is disconnected. The power established by the gas turbine is used to initiative the compressor and the remaining is used to initiative other machinery or generator. In the open cycle gas turbine the system and the working fluid are replaced continuously and gases are drained into the atmosphere. Then the total flow derives from the atmosphere and again returns to the surrounding.

2.3 CLOSED CYCLE GAS TURBINE:

In the closed cycle gas turbine, the compressed air from the surroundings is heated by using the heat exchanger (air heater). At constant pressure from the external source the heat is additionally given to the heat exchanger. High pressure working fluid increases over the turbine and then the power is developed. The exhaust working fluid must be cooled in a pre-cooler. Same fluid is sent into the compressor before the process is done. In the turbine same working fluid is always distributed. From an external source the fuel is required for adding heat so the fuel ranges from kerosene and then to the heavy oil.

3. COMPRESSOR

The gas turbines require high amount of air flow through the components and the process is a continuous one. To meet the requirements of high air flow, dynamic compressors are used. The dynamic compressors include centrifugal compressors and axial flow compressors. The type of compressor commonly used is GT'S are of axial flow type. This is due to the fact that centrifugal compressors are not suitable for multi staging and they have a smaller inlet area compared to the axial flow type, thus limiting the air flow.

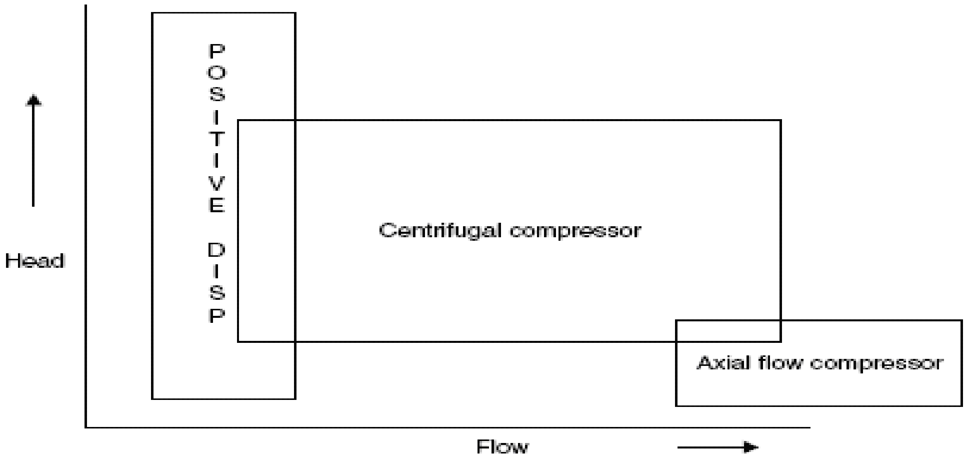

Figure.3.1: Performance characteristics of different types of compressors

3.1 AXIAL FLOW COMPRESSOR:

The air in an axial compressor flows in an axial direction through a series of rotating rotor blades and stationary stator vanes. The flow path of an axial compressor decreases in cross-section area in the direction of flow, reducing the volume of the air as compression progresses from stage to stage of compressor blades. The air being delivered to the face of compressor by the air inlet duct, the incoming air passes through the inlet guide vanes. Air upon entering the first set of rotating blades and flowing in axial direction, is deflected in the direction of rotation. The air is arrested and turn as it is passed on to a set of stator vanes , following which it is again picked up by another set of rotating blades , and so on , through the compressor . The pressure of the air increases each time that it passes through a set of rotors and stators. The aerodynamic principles are applied to the compressor blade design in order to increase efficiency. The blades are treated as lifting surfaces like aircraft wings or propeller blades. The cascade effect is a primary consideration in determining the aerofoil section, angle of attack, and the spacing between blades to be used for compressor blade design. The blade must be designed to withstand the high centrifugal forces as well as the aerodynamic loads to which they are subjected. The clearance between the rotating blades and their outer case is also very important. The rotor assembly turns at extremely high speed, and must be rigid, well aligned and well balance

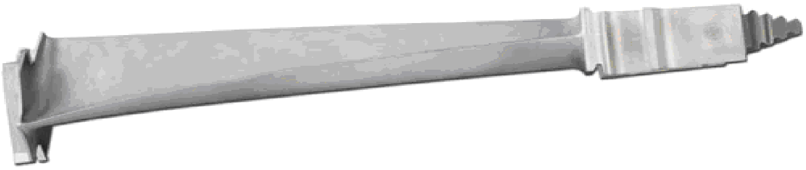

Figure.3.2: Compressor Blades.

The construction of the compressor is by discs and through b,lts. The blades are attached to the disc by a dovetail joint as shown in the figure above. The discs in turn are stacked together by the use of tie rods and the discs are tightened by the use of bolts. The compressor blades are made of Cr-Mo-V alloyed steel. The compressor casing is horizontally split. There are 4 bleed points in the compressor. The bleeding is performed from the 5th, 11th, 17th and CDC for sealing, surge prevention, cooling and atomizing. The compressor and the turbine are connected together with the aid of stub shafts.

3.1.1 COMBUSTION CHAMBER:

The type of combustion chambers in the GT unit is Reverse flow Can-annular combustion chambers. There are 14 combustion chambers arranged around the GT. Of the 14 chambers, only two combustion chambers, situated at the top are provided with the retractable spark plug. The flame from these chambers, pass on to the rest with the aid of the crossfire tube connection. The compressed air enters the chamber, mixes with the atomized fuel and takes a 180° turn to enter the combustion zone. The advantage of this combustion chamber is that it provides high turbulence, which aids in the complete mixing of fuel and air. The products of combustion leave the combustion chamber through the opposite end, to the turbine.

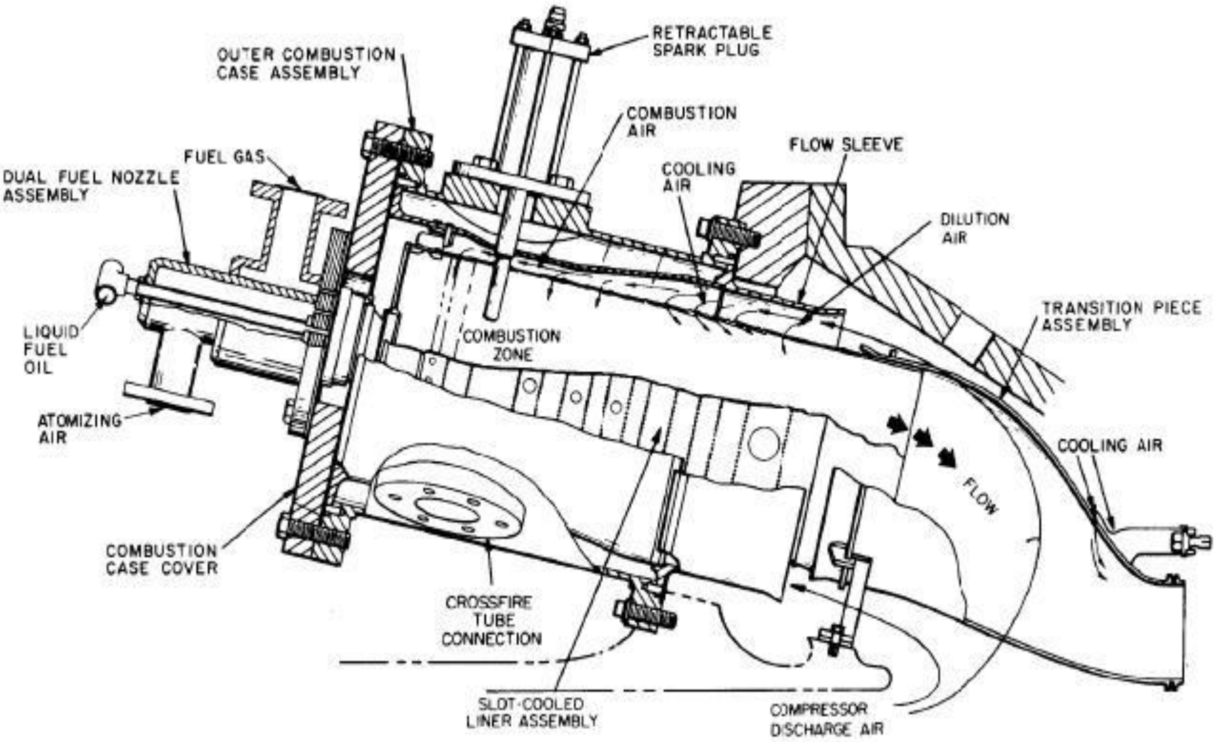

Figure.3.3: Reverse Flow Can-Annular Combustion Chamber

4. STEAM GENERATOR (BOILER)

The boiler is a closed vessel in which the given fluid is heated and evaporated. Steam boiler is one in which water is evaporated. It is why steam boiler is called steam generator. The basic elements of a boiler are shell, furnace, and heating source, heating surface, steam space, mountings and accessories. Shell of very small boilers, such as domestic, experimental, clinical etc., is made of copper or stain less steal. Big boilers have cast iron or steel shells. Furnace is the fire box of a boiler. The exhaust from the gas turbine is passing through the fire box of the boiler. The part of the boiler which is exposed to hot gases is called heating surface. When liquid is evaporated steam is produced. Here we are using water tube boilers. Water flows inside the tubes and hot gases surround the tubes. In water tube boilers, water to be evaporated is circulated inside tubes and gases flow over them. Surrounding hot gases conduct heat to the water inside the tubes.

5. SURFACE CONDENSER

Condenser is used to condense the exhausted steam from LP cylinder and to produce the deepest possible vacuum in order to increase the heat drop and the turbine o/p besides making it possible to reuse condensate thus obtained. Optimum utilization of steam space by providing rectangular cross section of the tube nest is an added feature of this condenser. For ensuring equitable loading of condenser tubes without incurring appreciable steam side pressure drop, tubes have been segregated in small bunches leaving wide lanes between them. Tube bundle has been kept ½ degree inclined towards front w/box side for self-draining during CW pump tripping.

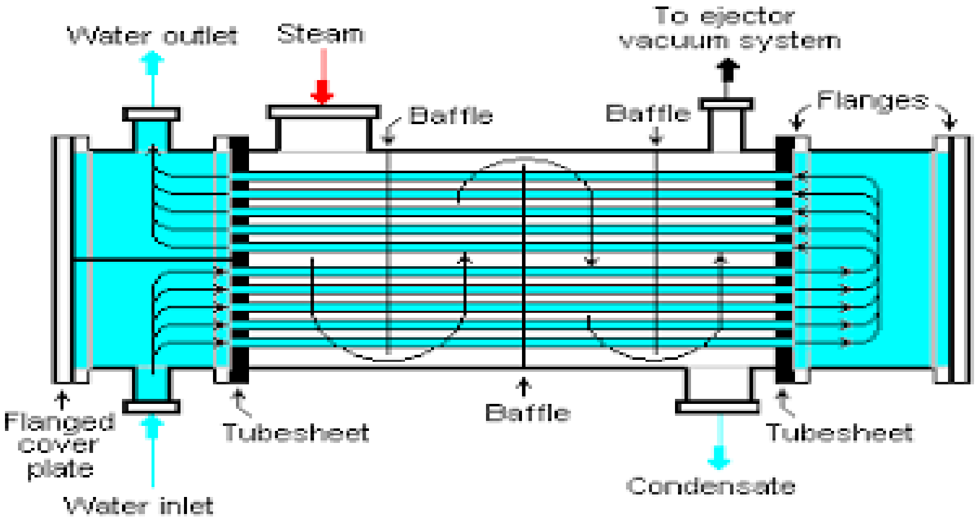

Figure.5.1: Condensers

The condenser also has the following secondary functions:

- The condensate is collected in the condenser hot well, from which the condensate pumps take their suction;
- Provide short-term storage of condensate;
- Provide a low-pressure collection point for condensate drains from other systems in the plant; and Provide for de-aeration of the collected condensate.

6. COOLING TOWERS

A cooling tower is an enclosed tower like structure through which atmospheric air circulates to cool large quantities of warm water. The cooling towers and spray ponds used for cooling the warm water pumped from the water cooled condensers. Then the same water can be used again and again to cool the condenser. The principle of cooling the water in cooling towers and spray ponds is similar to that of evaporative condensers that is the warm water is cooled by means of evaporation. The air surrounding the falling water droplets from the spray nozzles causes some of the water droplets to evaporate. The evaporating water absorbs latent heat of evaporation from the remaining water and thus cools it. The air also absorbs a small amount of sensible heat from the remaining water. The cooled water collects in the pond or in a sump at the cooling tower which is recirculates through the condenser

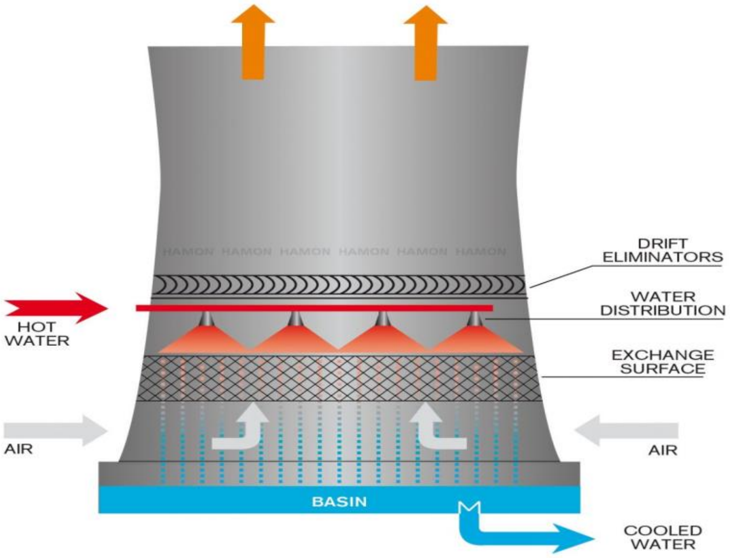

Figure.6.1: Natural Draft Type Cooling Tower

7. MODELING OF COMBINED CYCLE GAS TURBINE

A simple CCGT power plants having Brayton cycle based topping cycle and Rankine cycle based bottoming cycle has been considered for the present study and analysis. Gas turbine power plants consist of four components, compressor, combustion chamber, turbine and generator. Air is drawn in by the compressor and delivered to the combustion chamber. Liquid or gaseous fuel is commonly used to increase the temperature of compressed air through a combustion process. Hot gases leaving the combustion chamber expands in the turbine which produces work and finally discharges to the atmosphere. The waste exhaust gas temperature from gas turbine decreases as it flows into the heat recovery steam generator (HRSG), which consists of super heater, evaporator and economizer. Then the HRSG supplies a steam for the steam turbine in producing electricity. In the latter, the waste condensate from the steam turbine will be flowed into a condenser, where cooling water transfers waste heat to the cooling tower. In the final stage, feed water is the output

8. GAS TURBINE WITH INTERCOOLER

An intercooler is an intake air cooling device used commonly on turbocharged and supercharged engines. Intercooler cools the air compressed by the turbo/supercharger reducing its temperature and increasing the density of the air supplied to the engine. As the air is compressed by a turbo/supercharger it gets very hot, very quickly. As its temperature climbs, its oxygen content (density) drops, so by cooling the air, an intercooler provides a denser, more oxygen rich air to the engine thus improving the combustion by allowing more fuel to be burned. It also increases reliability as it provides a more consistent temperature of intake air to the engine which allows the air fuel ratio of the engine to remain at a safe level. The intercooled used to increasing the overall efficiency of a gas turbine power plant is to decrease the work input to the compression process. These effects increase of the net specific work outputs. In this process the air is compressed in the first compressor (low pressure compressor) to some intermediate pressure and so it is passed across an intercooler, where it is cooled off to a lower temperature at fundamentally constant pressure. It is suitable that the lower temperature is as low as possible. The cooled air is directed to high pressure compressor, where its pressure is further raised and then it is directed to the combustion chamber and later to the expander. A multistage compression processes is also possible. The overall result is a lowering of the net specific work input required for a given pressure ratio. However, intercooling used without reheating causes decrease of the efficiency leastways for small pressure ratios. It is explained by the drop of air temperature after the compressor, which is compensated by the increase of the temperature in the combustion chamber. Intercooling provides significant benefits to the Brayton cycle gas turbine power plant through decreasing the work of compression for the high pressure compressor (HPC), which allows for higher pressure ratios, thus increasing overall efficiency. The cycle pressure ratio is 42:1. The reduced inlet temperature for the HPC allows increased mass flow resulting in higher specific power. The lower resultant compressor discharged temperature provides colder cooling air to the turbines, which in turn allows increased firing temperatures at metal temperatures equivalent to the LM6000 gas turbine producing increased efficiency. The LMS100 system is a 2550°F (1380°C) firing temperature class design. In this paper, a parametric study for performance of gas turbine power plant with intercooled compression process. The effects of ambient temperature, pressure ratio, cycle peak temperature ratio, turbine inlet-temperature, air fuel ratio and the effectiveness of the intercooler on the gas turbine cycle performance is investigated

9. EQUATIONS USED FOR NUMERICAL ANALYSIS

It is assumed that the compressor efficiency and the turbine efficiency are represented ηc and ηth respectively. Using the first law of thermodynamic and knowing the air inlet temperature to compressor, compression ratio (r) and isentropic efficiency for compressor, we can determine the net work of the gas turbine (Wnet) is calculated from the equation:

$$\mathrm{Wnet} = \mathrm{Cpg} \times \mathrm{TIT} \times \eta\mathrm{t}\left(1 - \frac{1}{\mathrm{rp}^{\frac{\gamma g-1}{\gamma g}}}\right) - \mathrm{Cpa} \times \mathrm{T1} \times \left(\frac{\mathrm{rp}^{\frac{\gamma a-1}{\gamma a}} - 1}{1}\right) \quad (1)$$

Where, (Cpa): The specific heat of air which can be fitted by the following equation for the range of 200K<T<800K (R) and η m is the mechanical efficiency of the compressor.

$$\mathrm{Cpa} = 1.0189 \times 10^{3} - 0.1387 \times \mathrm{Ta} + 1.9843 \times 10^{-4}\mathrm{Ta}^{2} + 4.1399 \times 10^{-7}\mathrm{Ta}^{3} - 3.7632 \times 10^{-10}\mathrm{Ta}^{4} (2)$$

Where, Ta in Kelvin.

The specific heat of flue gas is given by,

$$\mathrm{Cpg} = 1.8083 - 0.1378 \times 10^{-3}\mathrm{T} + 4.045 \times 10^{-6}\mathrm{T}^2 - 1.7363 \times 10^{-10}\mathrm{T}^3 \qquad (3)$$

Where, T = TIT = turbine inlet temperature and LHV= fuel low heating value.

Also, the output power from the turbine (P) can be expressed as

$$\mathrm{Power, p} = \mathrm{ma} \times \mathrm{Wnet} \qquad (4)$$

The specific fuel consumption (SFC) can be determined by,

$$\mathrm{SFC} = \frac{3600 \times \mathrm{f}}{\mathrm{Wnet}} \qquad (5)$$

The heat supplied is also expressed as:

$$\mathrm{Qadd} = \mathrm{f} \times \mathrm{LHV(cv)} \qquad (6)$$

The gas turbine efficiency (Ƞth) is expressed as:

$$Ƞ_{th} = \frac{Wnet}{Qadd} \qquad (7)$$

10. GAS TURBINE ANALYSIS WITH INTERCOOLING

Consider replacing the isentropic single-stage compression from P_1 to P_2 with two isentropic stages from P_1 to P_2 and P_2 to P_3. Separation of the compression processes with a heat exchanger that cools the air at T_2 to a lower temperature acts T_3 to move the final compression process to the left on the T-S diagram and reduces the discharge temperature following compression to T_4. The work required to compress air from P_1 to P_2 in two stages is given by considering two compressors namely low pressure compressor and high pressure compressor. Therefore, work required by the low pressure and high pressure compressor depends upon their pressure ratios.

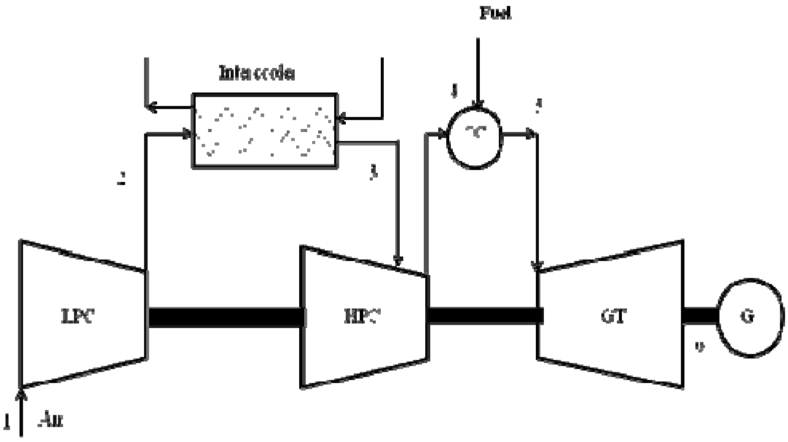

Figure.10.1: Schematic of Intercooling gas turbine cycle.

Numerical equations for the analysis of the gas turbine with intercooler can be derived from the T S diagram as shown in the figure;

Work of LPC,

W1= Cpa × (Tx'-T1) (1)

Work of HPC,

W2=Cpa × (T2'-T1) (2)

Total compressor work,

WCompressor = W1+W2 (3)
Total work with intercooler,
Wnet = Wt-Wc (4)

Note that intercooling increases the network of the reversible cycle. Thus intercooling may be used to reduce the work of compression between two given pressures in any application. However, the favourable effect on compressor work reduction due to intercooling in the gas turbine application may be offset by the obvious increase in combustor heat addition, and by increased cost of compression system.

11. RESULTS AND DISCUSSIONS

In the present work, two compressors high pressure (HP) and low pressure (LP) and a single turbine have been used for intercooling gas turbine cycle. For regenerative gas turbine cycle, one compressor and one turbine have been used for their analysis. The cycle was modelled using the thermodynamic analysis for the simple gas turbine, Intercooling gas turbine and regenerative gas turbine. The pressure losses are assumed in this work in various components. The effect of thermal efficiency, specific fuel consumption, pressure ratio across the compressor, turbine inlet temperature (TIT), ambient temperature (Tamb), and effectiveness of intercooler on the first-law efficiency and power are obtained by the energy balance approach or the first-law analysis of the cycle.

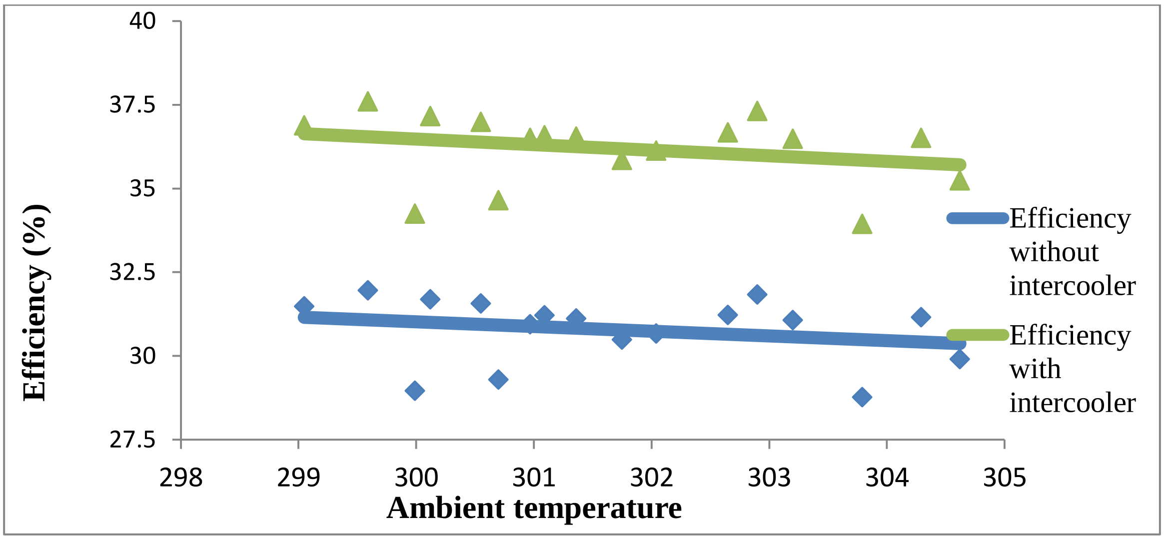

Figure.11.1: Ambient Temperature V/S Efficiency graph.

Figure shows the effect of ambient temperature on the efficiency of gas turbine cycle with intercooler effectiveness at a given value of turbine inlet temperature (TIT=1500 K) and compressor pressure ratio (r = 30). It is clear from the figure 11.1 that decreasing the ambient temperature increases the gain in efficiency.

Power output decreases on increasing the ambient temperature as shown in Figure 11.2

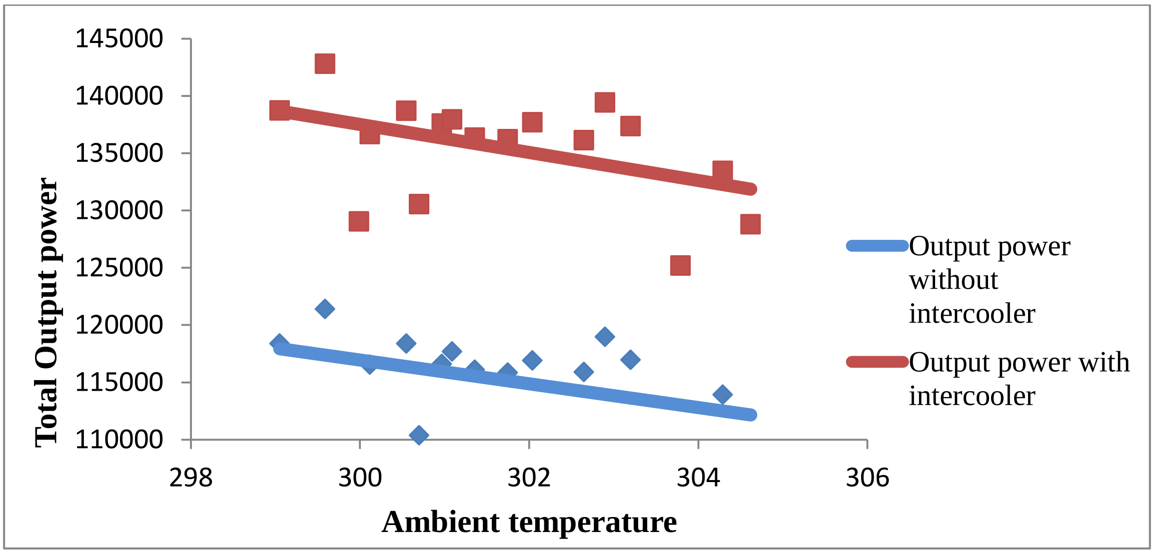

Figure.11.2: Ambient Temperature V/S Total output power graph.

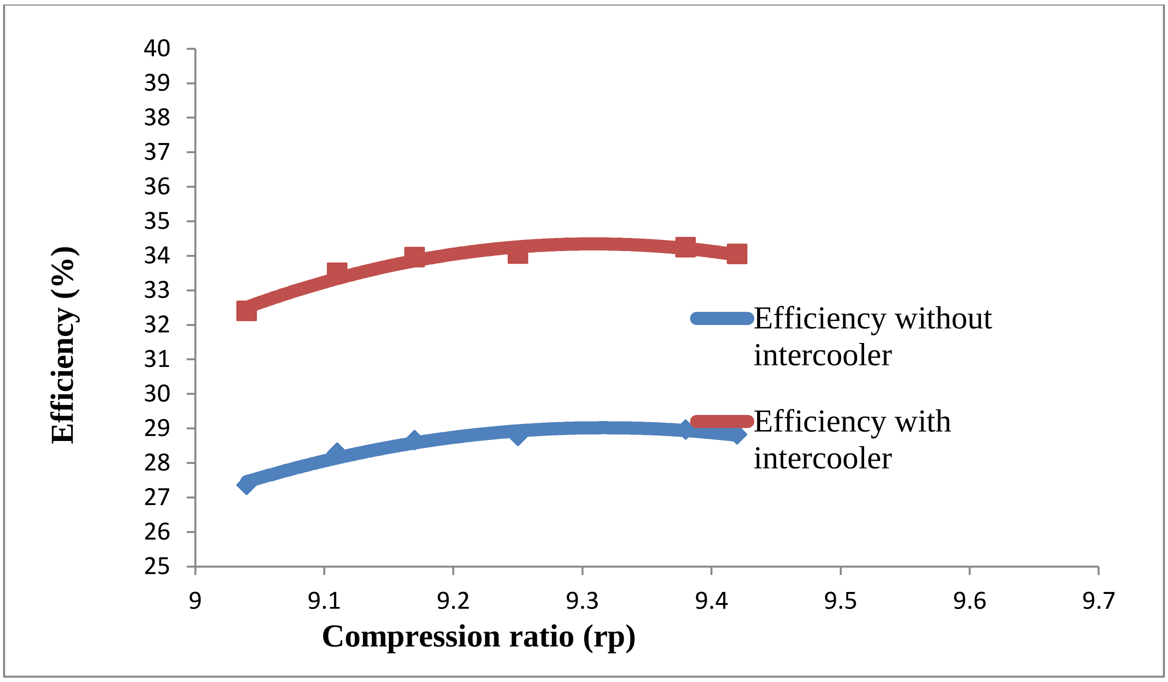

Figure11.3: Compression ratio V/S efficiency graph

Figure 11.3 shows that the efficiency of the gas turbine increases with the increase in compression ration as compression ratio also plays a vital role in the improvement in the efficiency of a gas turbine as this will increase further if we use an intercooler in the combined cycle power plant. In case of power output also when the ratio of compression increases then the total output power also increases this is shown in the figure 11.4 as the ratio of compression increases then the output power increases.

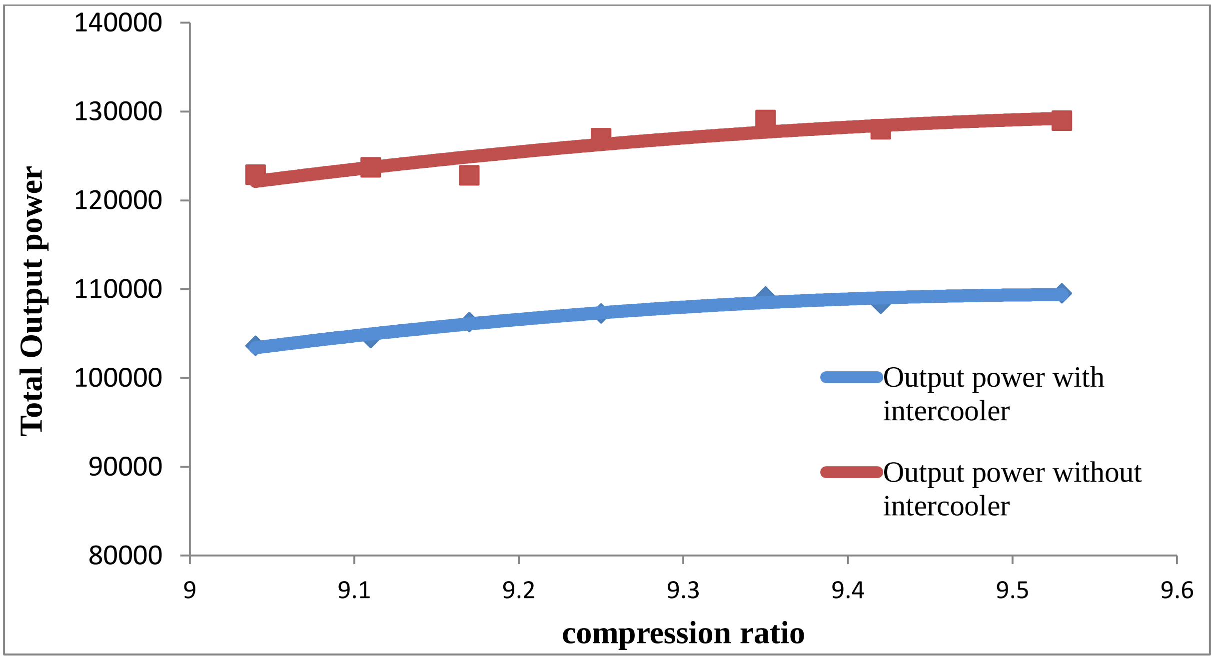

Figure.11.4: Compression ratio V/S Total output power.

Figure 11.5 shows the variation of compressor work with compressor pressure ratio for different values of intercooler effectiveness. It is to be noted that the compressor work increases on increasing the pressure ratio for a given value of atmospheric temperature and low pressure ratio. It also observed that the compressor work decreases on increasing the intercooler effectiveness for a fixed value of compressor ratio.

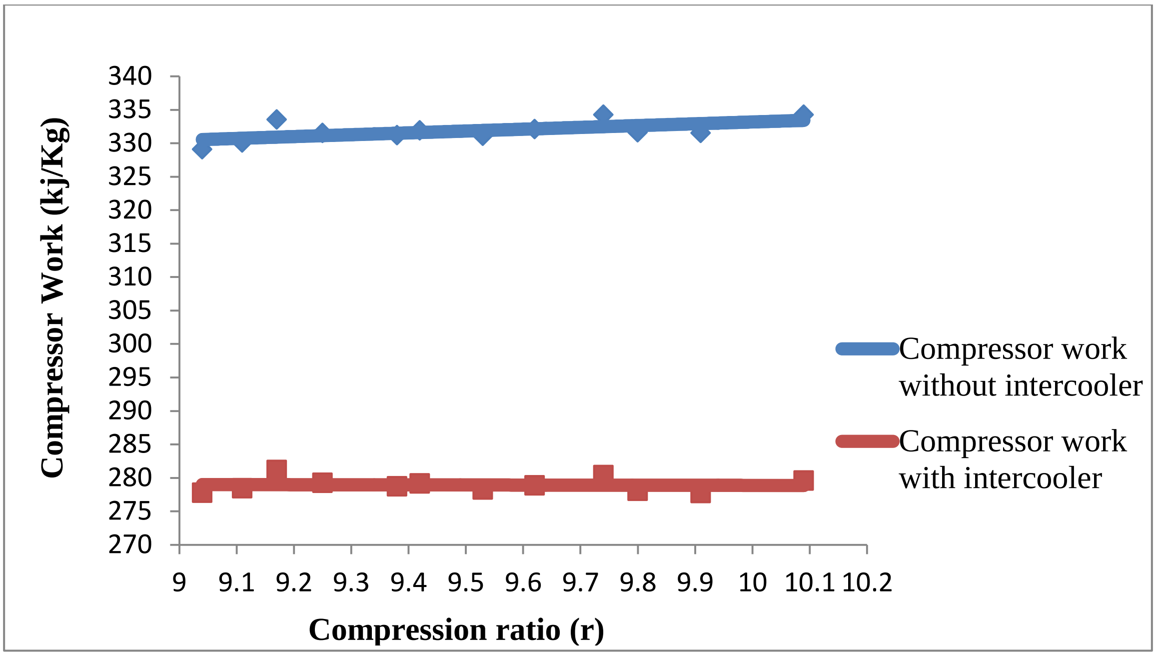

Figure.11.5: Compression Ratio V/S Compressor Work graph

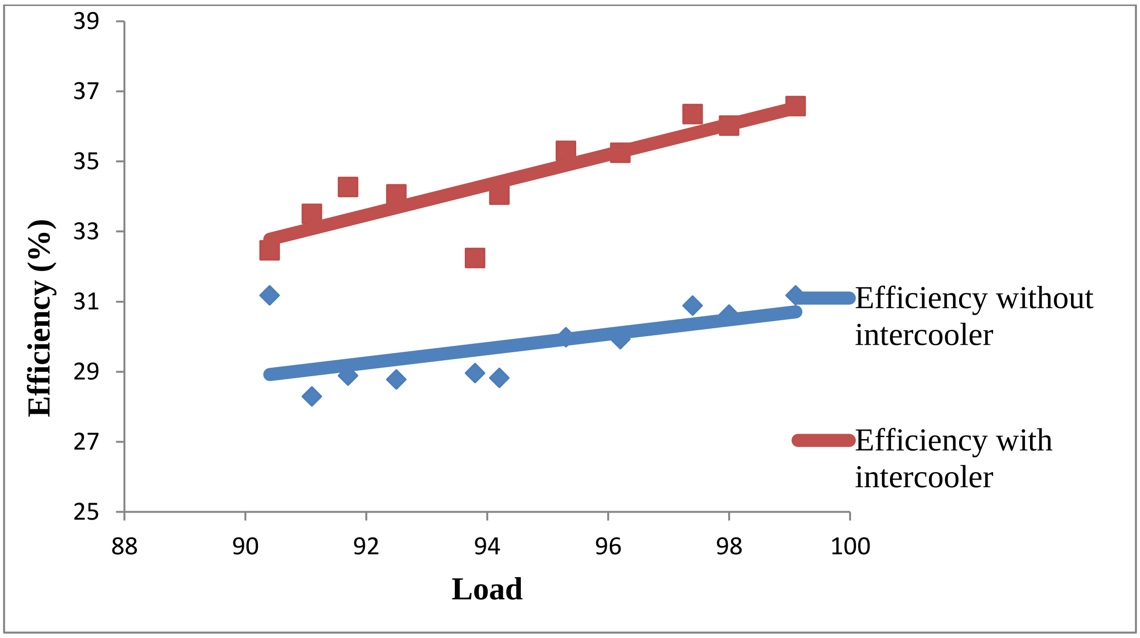

Figure.11.6: Load V/S Efficiency graph

Figure 11.6 shows the load and efficiency graph which means that at peak load the efficiency will be higher than at base load as the compression ratio increases the load also increases when without an intercooler the compression ratio is minimum but when an intercooler is placed then the ratio will increase as the intercooler will increase the compression ratio so the load will be at peak load and therefore an increase in efficiency will occurs. The simulation result from the analysis of the influence of parameter showed that total pressure ratio, turbine inlet temperature and ambient temperature effect on performance of gas turbine cycle with intercooler. The effects of various parameters influencing the gas turbine main characteristics are examined and the results of the case studied are compared based on different criteria such as power, specific fuel consumption, and thermal efficiency. The effect of total pressure ratio on total compressor work for various values of intercooler effectiveness The work required to run the compressor increased with increased the total pressure ratio but the work of compressor will decreased with increased the effectiveness for intercooler. Also the turbine inlet temperature decreases with increases the intercooler effectiveness and increases with increased the total pressure ratio, because decreases the work required to run the compressor and increases the turbine inlet temperature the power output increases with increases the total pressure ratio. The thermal efficiency increased with total pressure ratio at deferent values for intercooler effectiveness. Also the thermal efficiency increased about 40% when the total pressure ratio increased from 6 to 40.The variation of total compressor work with ambient temperature for various values of intercooler effectiveness. It shows that when the ambient temperature increases the total compressor work increases too. This is because, the air mass flow rate inlet to compressor increases with decrease of the ambient temperature. So, the total compressor work will increase, since air fuel ratio is kept constant. The power increase is less than that of the inlet compressor air mass flow rate; therefore, the total compressor work increases with the increase of ambient temperature but the total compressor work will decreases with increases the intercooler effectiveness. The turbine inlet temperature increased with increased ambient temperature and decreased with increased intercooler effectiveness. Figure 11.2 shows the effect of ambient temperature on the power output of intercooler gas turbine cycle. It is clear from the figure that decreasing the ambient temperature increases the gain in power output. As the ambient temperature increases, the total work of the compressors increases, thus reducing cycle efficiency for the intercooler gas turbine cycles.. A direct effect of inlet temperature on the standard air power output for simple gas turbine and the power output of gas turbine cycle with intercooler. As from the figure analysed it is clear that when the compressor work decreases the total power and the efficiency of the compressor increases this is done by reducing the compressor work make the energy of the turbine to utilize the power to run the compressor as this reduces the total work increases

12. CONCLUSIONS

The cycle calculation used in the intercooler gas turbine power plant analysis is correct. The examination of effect of varying parameters on the cycle performance is reliable. Comparatively an intercooled gas turbine power plant can offer a fuel consumption of 8% better than that of a simple cycle gas turbine, with a 5-9 % increase in power. As expected the higher total pressure ratio and cycle peak temperature ratio result in better performance.

The present work determined the performance of a intercooled gas turbine power plant. A design methodology has been developed for parametric study and performance evaluation of a intercooled gas turbine. Parametric study showed that compression ratio (r), ambient temperature and turbine inlet temperature (TIT) played a very vital role on overall performance of a regenerative and intercooled gas turbine. The simulation result from the analysis of the influence of parameter can be summarized as follows:

1. The thermal efficiency increases and specific fuel consumption decreases with increase in the intercooler effectiveness.

2. The thermal efficiency of the simple gas-turbine cycle experiences small improvements at large compression ratios as compared to gas turbine cycle with intercooler.

3. The peak efficiency, power and specific fuel consumption occur when compression ratio increases in the gas turbine cycle with intercooler.

4. Maximum power for the turbine inlet temperature is selecting an optimum value of compression ratio and turbine inlet temperature, which will result in a higher thermal efficiency. The cycle calculation used in the intercooler gas turbine power plant analysis is correct. The examination of effect of varying parameters on the cycle performance is reliable. Comparatively an intercooled gas turbine power plant can offer a fuel consumption of 8% better than that of a simple cycle gas turbine, with a 5-9 % increase in power. As expected the higher total pressure ratio and cycle peak temperature ratio result in better performance.

13. SCOPE FOR FUTURE WORKS

The analysis of this study can make some scope for the introduction of intercoolers in the power generation plants for future as it has many advantages as well as scopes which are mentioned below:

- Detailed economic study of configurations should be worked out to estimate the specific capital cost as well as plant capital cost which may help to choose configuration on the basis of better efficiency and specific work as well as on the cost.
- Work of the compressor can be reduced with it as by installing this we can reduce compressor work
- Detailed feasibility study for each configuration considering all practical aspects.
- Optimization of individual elements of different configurations can be attempted.

- Better mathematical models for every component may be developed for real situation.
- Better cooling model may be developed.
- Level of NO_2, SO_2 in the exhaust gas can be reduced.
- The intercooling pressure ratio plays an important role on the performance

REFERENCES

[1] P. Iora and P. Silva (2013), “Innovative combined heat and power system based on a double shaft intercooled externally fired gas cycle”, Applied Energy vol 105 pp108–115.

[2] Thamir K. Ibrahim et al. (2011), “Improvement of gas turbine performance based on inlet air cooling systems: A technical review”, International Journal of Physical Sciences Vol. 6(4), pp. 620-627.

[3] Basrawi, F., Yamada, T., Nakanishi, K. and Naing, S. 2011. Effect of ambient temperature on the performance of micro gas turbine with cogeneration system in cold region. Applied Thermal Engineering. 31: 1058-1067.

[4] Wadhah Hussein A. R. (2011), “Parametric Performance of Gas Turbine Power Plant with Effect Intercooler”, Modern

[5] Thamir K. Ibrahim, et al. (2010), “Study on the effective parameter of gas turbine model with intercooled compression process”, Scientific Research and Essays Vol. 5(23), pp. 3760-3770.

[6] Tiwari, A.K., Islam, M., Hasan, M.M. and Khan, M.N., 2010. Thermodynamic Simulation of Performance of Combined Cycle with Variation of Cycle Peak Temperature &Specific Heat Ratio of Working Fluid. International Journal of Engineering Studies. 2(3): 307–316.

[7] Espatolero, S., Cortés, C. and Romeo, L.M. 2010. Optimization of boiler cold-end and integration with the steam cycle in supercritical units. Applied Energy. 87: 1651-1660.

[8] M. M. Rahman, et al. (2010), “Thermal Analysis of Open-Cycle Regenerator Gas-Turbine Power-Plant”, World Academy of Science Engineering and Technology, 44.

[9] Rahim Ebrahimi (2009), “Thermodynamic simulation of performance of an end reversible Dual cycle with variable specific heat ratio of working fluid”, Journal of American Science 5 (5): 175-180.

[10] Sanjay, Singh O. and Prasad B. N. (2007), “Energy and exergy analysis of steam cooled reheat gas-steam combined cycle”, Applied Thermal Engineering 27, 2779–2790.

[11] Onovwiona, H.I. and Ugursal, V.I. 2006. Residential cogeneration systems: review of the current technology. Renewable and Sustainable Energy Reviews. 10(5): 389–431.

[12] R. Bhargava, et al. (2004), “A Feasibility Study of Existing Gas Turbines for Recuperated, Intercooled and Reheat Cycle”, pp 531-544.

[13] Sonntag, R. E. et al. (2003), “Fundamentals of Thermodynamics” John Wiley & sons Publications.

[14] Rice, I. G. 1980. The combined reheat gas turbine/steam turbine cycle. ASME Journal of Engineering for Power.102: 35-49.