Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **9(3),** 9-18, September **(2020)** *Res. J. Engineering Sci.*

A new integration system for combined power plant with heat recovery system and low emission

Umesh Kumar and M.K. Pal
Mechanical Engg. Department, Bhilai Institute of Technology, Durg-491001, CG, India
umeshsahu51@gmail.com

Available online at: www.isca.in, www.isca.me
Received 29th November 2019, revised 30th May 2020, accepted 15th July 2020

Abstract

The combined power plant has importance features is its relatively low capital investment and environment advantages compared with the conventional power plant. The conventional power plants have lower efficiencies. Now a days for the new integration improvement system is the ''combined cycle power plant''. In current situation the combined cycle power plant is new technology and its offers optimum efficiency to any of the gas turbine power plant. In this paper comparing four different cycles to analysis optimization of waste heat Recovery: i. Gas turbine, ii. Reheat steam turbine, iii. Steam turbine without Reheat, iv. Steam turbine power plant. The new integration system combined cycle plant would produce 100 MW of power (67 MW from the gas turbine and 33 MW from the steam turbine). The gas turbine cycle is more effective using the combined cycle power plant and its higher efficiency. The initial way to adopted is the four cycle of the possible of the combined power plant. Now, the selection of gas turbine cycle, the next step is to analysis the impact of the steam cycle design and parameters on the general performance of the plant. Each alterative cycle was analysed, getting to find the simplest possible option from the standpoint of overall efficiency, installation and operational costs, maintainability and reliability for a combined power station. There are several schemes are proposed for investigation. During this paper to seek out the overcome of the restrictions of the traditional analyses and to extend our knowledge a few plant, advance Heat Recovery Steam generator with low emission exergy have been developed. Resulting in the Gas turbine output is 67.8 MW, steam turbine output is 34.8 MW. Steam cycle efficiency is 22.5% and the overall efficiency is 53.2%. Net power output of plant 101.4 MW. Utilization rate of waste heat energy 62.4%. The results indicated that the utmost exergy loss within the turbine cycle occurs within the combustion chamber thanks to its high irreversibility because the second major exergy loss is in HRSG, the optimization of HRSG has a crucial role in reducing the exergy loss of combined cycle.

Keywords: Power Enhancement, Exergy analysis, Flue Gas Loss, Combined cycle, Gas turbine cycle, Reheat steam turbine, Steam turbine without Reheat, gas turbine, Steam turbine power plant, CO_2 removal.

Introduction

Energy security and Environment pollution are two major concerns of today's world. Improving efficiency of the energy systems is extremely important for future energy and reduction of CO_2 for safe environment. The Inter governmental Panel on global climate change (IPCC), in its Fourth Assessment Report[1] identified CO_2 emissions from burning of fossil fuels because the main and first contributor to global climate change. With the rapid development of the world's economy, the consumption of fossil fuels is predicted to extend constantly within the short term future, which makes the environmental issues caused by atmospheric emissions more serious[2].

It's predicted that the world's electricity demand will increase continually up to 35,390 TWh by 2030, 20% of which can be generated from the gas Combined Cycle (NGCC) power plants[2]. Therefore, it's essential to seek out an efficient approach to understand the carbon mitigation of latest Gas combined Cycle power plants.

The economy of India, India may be a developing country, has grown rapidly in recent years, alongside the more electrical demand. In recent years, the utilization of turbine for power generation has increased dramatically worldwide because its optimum efficiency. Consistent with world energy forecasts, fossil fuels like coal, oil, and gas will still be the important energy sources for power generation within the near future in India also as worldwide. The thermal efficiency of turbine combined cycle (GTCC) power plants will reach that's far more energy than of conventional power plants, which not only conserves our limited reserves but also reduces emissions and protects our lives and environment. The traditional methodology of energy analysis is based on 1st law of thermodynamics that focuses on the conservation of energy. The limitation with this analysis is that it doesn't take into account properties of the system setting or degradation of the energy quality of the dissipative processes. Moreover, the first law associate analysis usually casts deceptive impressions concerning the performance of an energy conversion device.

To realize optimum efficiency therefore, a better order analysis supported the second law of thermodynamics as this permits us to spot the main sources of loss, and shows avenues for improvement the performance[3]. In recent years, the performance of commercial gas turbines has been improved, thanks to considerable investments in research and development, in terms of fuel to electricity conversion efficiency, plant capacity, availability and reliability. The larger handiness of fuel resources, like gas (NG) the various reduction in capital prices and thus the introduction of advanced cycles have additionally been successful issue for increased development of gas turbines for base load applications[4]. The gas prices fell and turbine technologies improved. The upsurge within the use of commercial gas turbines is usually focused on the Combined Cycle power station using the straightforward cycle for the turbine. Combined cycle plants reached thermal efficiencies of quite 50%. It's thought that within subsequent decade and even by the turn of the century, it'll be possible to supply a CCPP with thermal efficiencies on the brink of 59%.

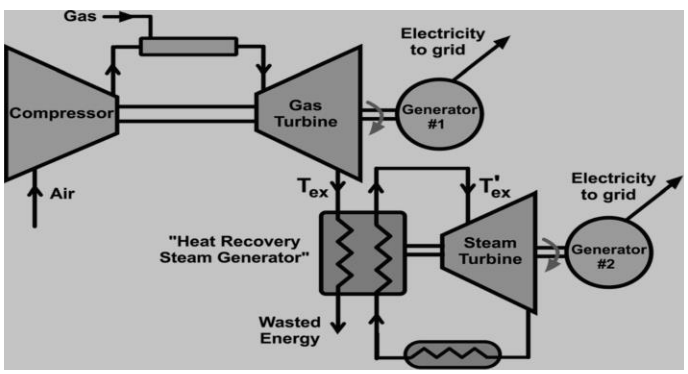

Figure-1: Sketch diagram of combined cycle power plant.

Combined Cycle -Water/ Steam Cycle Concepts

The most challenge in designing a combined-cycle plant with a turbine is the way to transfer the turbine exhaust heat to the steam cycle to get optimum turbine output. The main target is on the HRSG during which the warmth transfer between the gas cycle and therefore the steam cycle takes place. The energy exchange that would take place in an idealized heat exchanger, in which the product (mass flow times specific heat capacity or the energy transferred per unit temperature) must be the same in both media at any point so that there are minimum exergetic losses in a given heat exchanger. The heat transfer in a HRSG losses associated with three main factors: i. The physical properties of the water, steam and exhaust gases don't match the upper exergetic losses than those of an idealized device. ii. The warmth transfer surface can't be infinitely large. iii. The temperature of the feed-water must be high enough to stop forming corrosive acids within the exhaust gas, where it comes in touch with the cold tubes within the HRSG. This minimum feed-water temperature limits the energy utilization in the HRSG (temperature to which cooled the exhaust gas).

The extent of loss minimization (maximum heat utilization) depends on the concept and parameters of the cycle. In a more complex cycle the heat will generally be used more efficiently, improving the performance but also increasing the cost.

Fuels for Combined Cycle Power Plants: The turbines utilized in Combined Cycle Plants square measure sometimes hopped-up by gas, though fuel, synthesis gas or different fuels are often used.

Emissions Control Selective Catalytic Reduction (SCR): To control the CO_2 emissions within the exhaust gas so it remains inside allowable levels because it enters the atmosphere, the exhaust gas passes though two catalysts located within the HRSG. One catalyst controls monoxide (CO) emissions and also the various catalyst controls Oxides of element, (NOx) emissions. Aqueous Ammonia additionally to the SCR, Aqueous Ammonia (a mixture of twenty-two ammonia and 78% water) is injected into system to even further reduce levels of NOx.

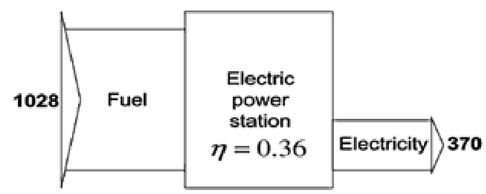

Figure-2: Electric power station.

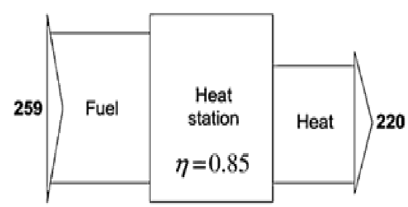

Figure-3: Heat station.

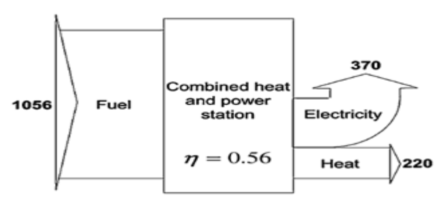

Figure-4: Combined heat and power station.

Merits Fuel efficiency: In standard power plants rotary engines have a fuel conversion potency of 33 you which of them suggest 66% of the fuel burned to drive the turbine off. The turbines in combined cycle power plant have a fuel conversion potency of fifty or tons of, which suggests they burn about half amount of fuel as a standard plant to get same amount of electricity.

Abundant fuel sources: The turbines utilized in combined cycle plants are fuelled with gas, which is more economy than a coal or oil and may be utilized in 85% of energy production.

Reduced emission and fuel consumption: Combined cycle plants use least fuel per kWh and low emissions than conventional thermal power plants, thereby reducing the environmental damage caused by electricity production.

Potential applications in developing countries: The potential for combined cycle plant is with industries that needs electricity and heat or steam. For instance to utilize electricity and steam to a Sugar refinement mill.

Cycles with alternative working media

Another way of improving the efficiency of a combined-cycle plant is using fluids other than pure water/steam in the bottoming cycle. The idea is using a mixture of fluids, such as water mixed with ammonia; the evaporation in the HRSG will no longer take place at only one temperature but over a range of temperatures. This serves to reduce the exergy loss between exhaust gas and working fluid, thereby increasing the efficiency. The cycles operate at only one pressure and theoretically more suitable for gas turbines with relatively low exhaust temperatures, such as aero derivative machines. Condensation takes place at more than one temperature, which complicates the condensing system. Another disadvantage is that this cycle relates to the toxicity or aggressiveness of the fluids used. Leakages could lead to environmental pollution or health problems.

As gas turbines develop towards higher inlet and exhaust gas temperatures, the advantages of these alternative working media for combined-cycle plants.

Heat Recovery Steam Generator

In Heat Recovery Steam Generator sublimate water flows in tubes and also the recent gases passes a around to steam. After generation the steam then rotates the turbine and paired generator to supply Electricity. The recent gases leave the HRSG at around 135^0C and discharged into the atmosphere. The warmth recovery steam generator (HRSG) is that the link between the turbine cycle and therefore the turbine cycle. There are three main categories: i. Heat Recovery Steam Generator without supplementary firing. ii. Heat Recovery Steam Generator with supplementary firing. iii. Steam generators with maximum supplementary firing.

HRSGs without supplementary firing are most vital features in combined cycle plants. The function of the HRSG is converting the exhaust gas into steam in turbine cycle. After heating within the economizer, water enters the drum, slightly sub-cooled state. From the drum, it's circulated to the evaporator and returns as a water or steam mixture to the drum where water and steam are separated. The saturated steam leaves the drum for the super-heater where it reaches the utmost heat exchange temperature with the most well liked exhaust-gas leaving the turbine. The warmth exchange in an HRSG can happen on up to 3 pressure levels counting on the specified amount of energy and exergy to be recovered. In present situation, two or three pressure levels of steam generation are most ordinarily used.

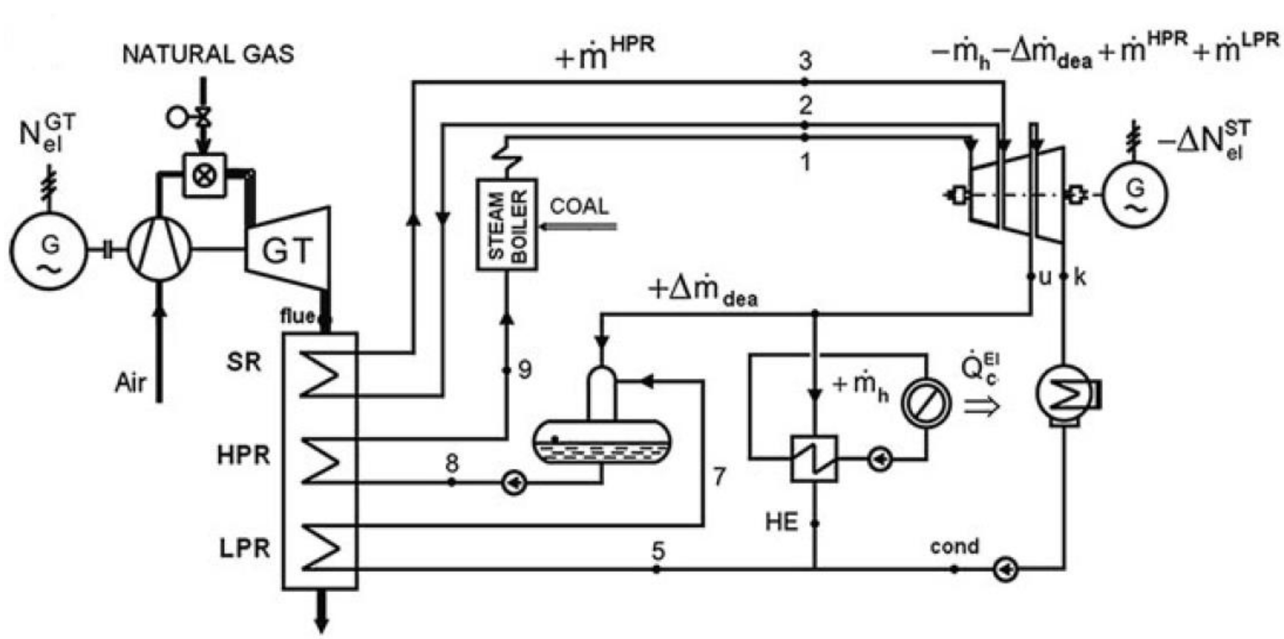

Figure-5: Steam power station adapted to cogeneration by gas turbine in parallel system.

Heat recovery: Waste heat from extracted steam is released by extracted steam for 14–17% of the entire energy losses for CO2 capture, which is attributed to the subsequent two reasons: Firstly, in decarbonisation power plants, the absorbent regeneration heat is usually supplied by the extracted steam, whose parameters are generally above the need of re-boiler. Therefore, it must be throttled and cooled to some suitable temperature and pressure before getting into the re-boiler, leading to an outsized energy wastage. Secondly, the re-boiler physical phenomenon ought to be cooled down before stepping into condenser to verify the operation safety, which increases the energy penalty of CO_2 capture also. Waste heat in flue gas the cooling heat of the flue gas constitutes 15-20% of the entire energy losses during a dioxide capture process. It's as a results of the flue gas in NGCC power plants doesn't need to undergo flue gas de-sulphurizer (FGD) to urge obviate the SOx before stepping into dioxide capture system, which results in the flue gas temperature before stepping into dioxide capture system being above that in coal-fired power plants with FGD. So as to reinforce the chemical reaction in absorber, the flue gas should be cooled down firstly, which suggests an excellent deal of low-temperature heat (40-120^{0}C) is dissipated.

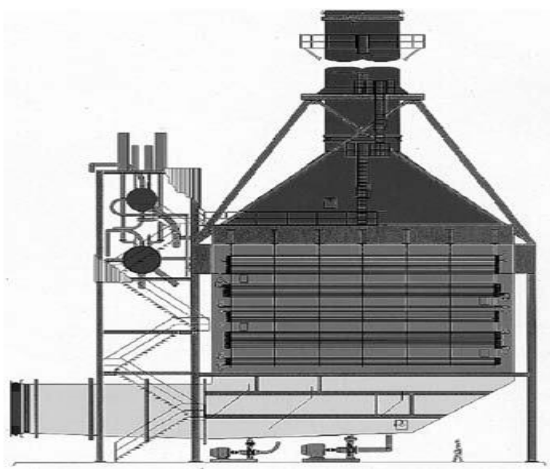

Figure-6: Forced circulation heat recovery steam generator.

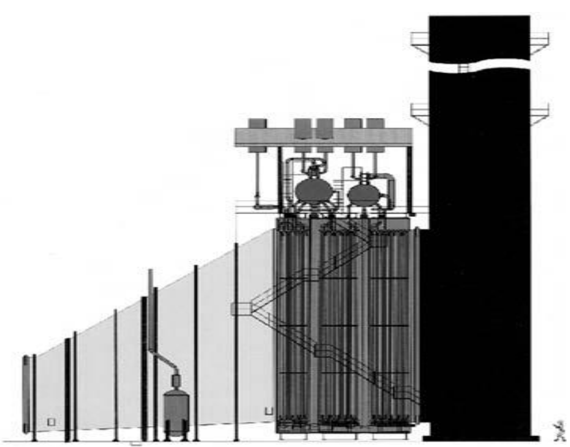

Figure-7: Natural circulation heat recovery steam generator.

Heat Recovery Steam Generator (HRSG) without supplementary firing Construction: An HRSG without supplementary firing is vital convective device. The wants imposed by the operation of the combined-cycle power station are often underestimated. Especially, provision must be made to accommodate the short start-up time of the turbine and therefore the requirements for quick load changes. The HRSG must be designed for top reliability, availability and cheaper. HRSGs are often design in two basic constructions, supported the direction of turbine exhaust flow through the boiler.

Vertical Heat Recovery Steam Generator: within the past, vertical HRSGs were most frequently referred to as forced-circulation HRSGs due to the utilization of circulating pumps to supply positive circulation of boiler water through the evaporator sections. During this sort of boiler, the warmth transfer tubes are horizontal, suspended from un-cooled tube supports located within the gas path. Vertical HRSGs also can be designed with evaporators that function without the utilization of circulating pumps. Figure-4,5 shows a forced circulation HRSG. The exhaust-gas flow is vertical, with horizontal tube bundles suspended within the steel structure. The steel frame of the steam generator supports the drums.

Horizontal Heat Recovery Steam Generator: The horizontal sort of HRSG has typically been referred to as the natural-circulation HRSG because circulation through the evaporator takes place entirely by gravity supported the density difference of water and boiling water mixtures. During this sort of boiler, the warmth transfer tubes are vertical, and essentially self-supporting. The exhaust-gas flow is horizontal. The steel structure is more compact than on a unit with vertical gas flow.

Design Comparison: Either type-vertical or horizontal-can be used in a combined-cycle plant. In the past, vertical HRSGs had several advantages that made them especially suited for combined-cycle applications: i. Minimum space requirements arising from the vertical design. ii. Smaller boiler volumes because of the use of smaller diameter tubes. iii. Less sensitivity to steam blockage in economizers during start-up.

The main advantage of the horizontal HRSG is that no circulation pumps are needed-an important point for applications with design pressures above 100 bar, where pumps must be designed and operated with special care. Additionally, there is an advantage with vertical tubes in the evaporator since the tubes with the highest heat absorption in the evaporator have the most vigorous circulation, and tube dry-out can't occur in vertical tubes. Current design for natural-circulation boilers has overcome the disadvantages relative to vertical boilers. Space requirements and start-up times are identical, water volumes in evaporators have been reduced with use of smaller diameter tubes, and steam blockage is better handled in a modern, natural circulation boiler. The same pinch-points can be achieved in the high and intermediate-pressure evaporator. Only in large HRSGs with a tight low pressure pinch-point do differences occur in steam performances. The presence of both technologies on the market indicates that both meet customer expectations and the preference for one or the other is more on a historical or on a regional preference (e.g., in North America, the overwhelming majority of HRSGs are of natural circulation design).

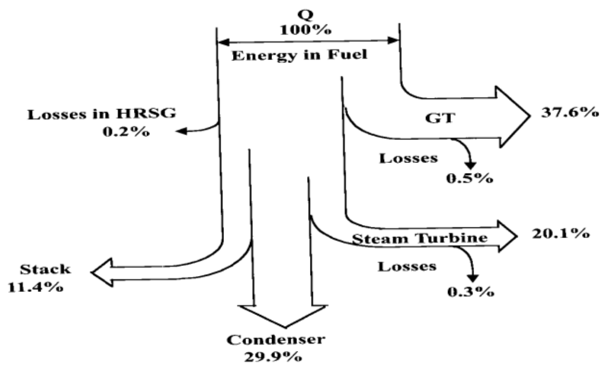

Figure-8: Energy Flow sketch for the Single Pressure Combined Cycle Plant.

Environment considerations

The impact of environment of any power station must be kept as low as possible, but striking an inexpensive relationship between the value and therefore the results obtained should function a suggestion even for those liable for making and enforcing the regulation. The subsequent emission from an influence station directly affects the environment: i. Products of combustion (exhaust and ash), ii. waste heat, iii. noise, iv. Radioactivity and nuclear waste. The exhausts can include the subsequent components NO, NO_2, CO_2, CO, C_nH_n (unburned hydrocarbon, UHC), SO_2, SO_3, dust, ash, heavy metals, chlorides, etc negatively effect on the environment. However, a high efficiency always work-out positively since the proportion of emission per unit of electricity produced drops off. A combined cycle plant is useful due to its high efficiency and therefore the high excess air coefficient customary in turbine produce a practically complete combustion i.e, a really low concentration element like unburned hydrocarbons. Most of the days when the fuel burned is gas, the sole toxic emission contained within the exhaust are not any and NO_2. The NOX(NO+NO_2) level is that the common environment problem with turbine because NOX generates aqua fortis H_2NO_3 and this along side vitriol H_2SO_4 is one among the factors liable for acid precipitation in atmosphere. Combined cycle power station forms the foremost effective plant of reducing the consumption of primary fuels and thus, decreasing the emission of hazardous products of combustion into the environment[6]. Especially, it might be liable for reduce the emission of greenhouse gases. Therefore, it's important to concentrate to the system integration between the energy utilization system and CO_2 capture process getting to recover the low-grade energy and reduce the energy penalty. During this study, an improved system of latest Gas Combined Cycle power station with CO_2 capture and warmth supply was developed, which recovers the sensible heat of flue gas to get electricity through a CO_2 and reutilizes the relative low heat released from the CO_2 capture subsystem for a radiant floor heating subsystem. In summary, the mixing measures proposed during this study are effective in enhancing internet efficiency of power plants with an inexpensive increment of investment, which provides an efficient and economic possibility for greenhouse emission removal from NGCC power plants. Exhaust emissions to the environment are mainly controlled within the turbine. However, the greater the efficiency of the installation, the greater the drop-off within the proportion of emissions per unit of electricity produced. Because most combined cycle plants burn gas, they produce low exhaust emissions. Their high efficiency leads to low air emissions per MWh of electric power produced and a coffee amount of waste heat. The high excess air ratios customarily found in gas turbines enable practically complete combustion to require place, which ends up during a very low concentration of unburned elements like CO or UHC within the exhaust. Therefore, a combined cycle plant are often considered to be environmentally friendly and compatible to be used in heavily populated areas. For plants burning gas, the foremost relevant emissions within the exhaust are not any and NO_2, NOx (NO and NO_2) emissions generate aqua fortis (H_2NO_3) within the atmosphere which along side sulphuric and sulphurous acids (H_2SO_4, H_2SO_3) are factors liable for acid precipitation. CO_2 is made by burning fossil fuels and is held liable for heating.

Waste Heat Rejection

Another environmental concern is that the waste heat that each thermal power plant releases to the environment. additionally to the number of waste heat, however, the shape during which the warmth is given to the environment is additionally important. The effect is a smaller amount if the facility plant heats air rather than giving off its waste heat to a river or the ocean. Conventional steam power plants often dissipate the waste heat to water for efficiency reasons. The most economic solution for combined cycle plants is frequently to dissipate the heat to the air through a wet cooling tower. Direct air-cooling is also possible, but results in a reduction in output and efficiency together with increased costs due to the air-cooled condenser. A combined cycle plant needs only half the cooling water of a conventional steam plant of the same output and a third of what is required for a nuclear power station. A gas turbine usually requires practically no external cooling except for the lube oil and generator, which has contributed greatly to its widespread acceptance in countries where water is scarce.

Due to the fact that the steam portion of the combined-cycle plant accounts the literature has often suggested combining two or more thermal cycles within one power station. Altogether cases, the intention was to extend efficiency over that of single cycles. Thermal processes are often combined this manner whether or not they operate with an equivalent or with different working media. However, a mixture of cycle with different working media is more interesting because their advantages can complement each other. Careful selection of the working media makes it possible to make an overall process that make optimum thermodynamics use of the warmth within the upper range of temperature and returns waste heat to the environment at as low a temperature level as potential. Normally the topping and bottoming cycle are coupled during a device. Up to the present time just one combined cycle has found wide acceptance. The combination turbine or turbine power station, thus far plant of this sort have burned generally fuel (principally liquid or gases). The best thanks to improve the method efficiency is to scale back these losses, which may be accomplished by raising the utmost temperature within the cycle, or by releasing the waste heat at as low a temperature as possible.

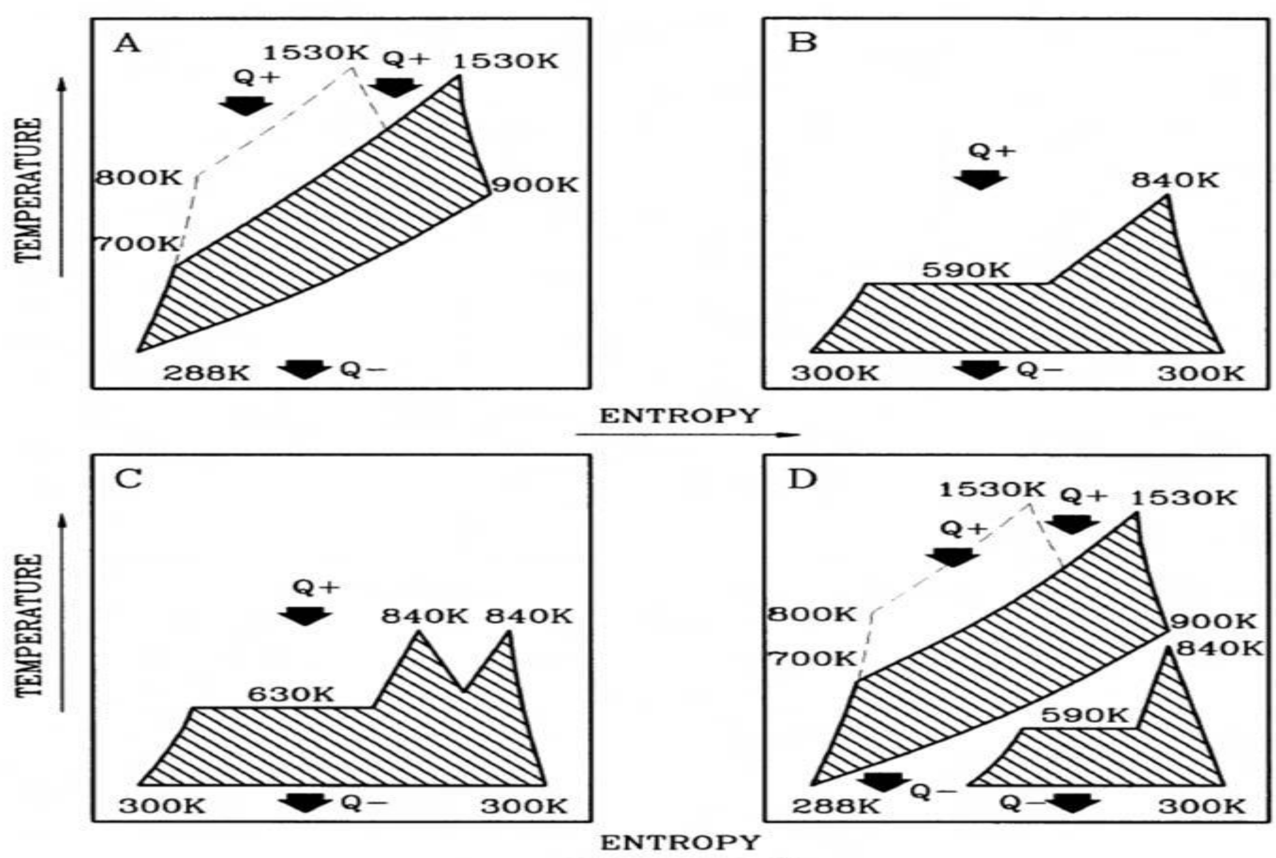

Figure-9: Temperature Vs Entropy diagrams, a. Gas turbine, b. Reheat steam turbine, c. Steam turbine without Reheat, d. Combined cycle gas turbine/steam turbine power plant.

Table-1: Thermodynamics comparison of gas turbine, steam turbine and combined cycle power plant.

Component	Gas turbine	Steam power plant with Reheat	Steam power plant without Reheat	Combined cycle power plant
Average temperature of the heat supplied in k	940-1010	650-710	560-640	960-1020
Average temperature of Exhaust heat in K	520-560	330-340	340-360	330-370
Actual Efficiency, in %	32-37	35-44	27-40	53-58

Table-2: Efficiency of Different power plant.

Type of Plant	Capacity	Net Efficiency
Combined cycle power plant	800 MW	54-58 %
Combined cycle power plant	58 MW	49-53 %
Gas turbine cycle	250 MW	36-38 %
Gas turbine cycle	59 MW	34-41 %
Steam power plant (coal)	800 MW	43-48 %
Steam power plant (coal)	61 MW	31-34 %
Nuclear power plant	1250 MW	34 %
Biomass power plant	30 MW	30-31 %

Table-3: Lists the fuel that can be burned in different types of power plants todays.

Fuel	Steam power plant	Gas Turbine	Combined Cycle
Natural gas/LNG	Yes	Yes	Yes
Crude oil/heavy fuel	Yes	Yes	Yes
Coal	Yes	No	No
Biomass	Yes	No	No
Coal gas, low calorific gas	Yes	Yes	Yes
Nuclear fuel	Yes	No	No

As shown by Figure-4, which analysis the temperature Vs Entropy diagrams of the four processes, the combined cycle is utilises the temperature differential within the heat supplied, albeit there's a further exergy loss between the gas and therefore the steam processes. Thermal Efficiency of the combined cycle plant, it had been assumed section that fuel energy is being supplied only within the turbine. There are however combined cycle installation with additional firing within the steam generator, during which some of the warmth is supplied on to the steam process. Accordingly, the overall definition of the thermal efficiency of a combined cycle plant:

$$\eta = \frac{Pgt+Pst}{Qgt+Qsf} \quad (1)$$

If there is absent of supplementary fires in the losses heat boiler (heat supplied Qsf = 0)

$$\eta = \frac{Pgt+Pst}{Qgt} \quad (2)$$

The efficiency of the single one cycles can be defined as follows for the gas turbine cycle

$$\eta_{GT} = \frac{Pgt}{Qgt} \quad (3)$$

For steam turbine cycle

$$\eta_{ST} = \frac{Pst}{Qgt+Qexh} \quad (4)$$

$$Q_{exh} = Qgt\,(1\text{-}\eta_{GT}) \quad (5)$$

Combination the two equations:

$$\eta_{ST} = \frac{Pst}{Qsf+Qgt(1-\eta GT)} \quad (6)$$

The fires in the losses heat boiler on overall efficiency substituting Equation (3) and (6) into Equation (1), one obtains:

$$\eta_{ST} = \frac{Qgt(1-\eta GT) + \eta ST(Qst+Qgt\{1-\eta GT\})}{Qsf+Qgt(1-\eta GT)} \quad (7)$$

firing within the losses heat boiler improves the overall efficiency of the combined cycle installation whenever:

$$\frac{\partial \eta k}{\partial Qsf} > 0 \quad (8)$$

Differentiation of Equation (8) produces the inequality:

$$\frac{\partial \eta k}{\partial Qsf} = \frac{1}{(Qgt+Qsf)^2}\{\eta GT\,.\,Qgt(\frac{\partial \eta sf}{\partial Qsf}\,Qsf + \eta sf).\ (Qgt + Qsf)\text{-}\ \eta sf.\,Qsf + \left[\frac{\partial \eta k}{\partial Qsf}\,Qsf - (1-\eta sf)\right].(Qgt+Qsf) - \eta ST.\,Qgf(1-\eta sf)\} > 0 \quad (9)$$

This yields:

$$\frac{\partial \eta sf}{\partial Qsf}\,Qsf[Qsf + Qgt(1-\eta sf)] + \eta sf >> \frac{\eta GT.Qg+\eta st[Qsf+Qgt(1-\eta GT)}{Qgt+Qsf} \quad (10)$$

Therefore the 2rd term of the inequality is equal to K, the equation reduces to:

$$\frac{\partial \eta sf}{\partial Qsf}\,[Qsf + Qgt(1-\eta sf)] > \eta K - \eta ST \quad (11)$$

The term $[Qsf + Qgt(1-\eta sf)]$ is none other than the heat input to the steam cycle. The formula thus becomes:

$$\frac{\partial \eta sf}{\partial Qsf}.\frac{Pst}{\eta st} > \eta K - \eta st \quad (12)$$

Equation (12) means increasing the firing improves the efficiency of the combining cycle plant as long as it improves the efficiency of the steam process. The efficiency of the combining cycle installation increase much more rapidly than that of the steam process, continually increase the difference (ŊK-ŊST). It's generally better to burn the fuel during a modern turbine, because the warmth is supplied to the method at a temperature level above that within the steam process. Efficiency of combined cycle plant without Additional firing within the waste heat boiler:

Without additional firing Equation (7) can be written as follows

$$\eta K = \frac{\eta GT.Qgt + \eta st.Qgt(1-\eta GT)}{Qgt} = \eta GT + \eta ST(1 - \eta GT) \quad (13)$$

Analysis makes it possible to estimate the effect that a change in efficiency of the gas turbine has on overall efficiency:

$$\frac{\partial \eta k}{\partial \eta GT} = 1 + \frac{\partial \eta k}{\partial Qsf}(1 - \eta GT) - \eta GT \quad (14)$$

Increasing the gas turbine efficiency improves the overall efficiency only if:

$$\frac{\partial \eta k}{\partial \eta GT} > 0 \quad (15)$$

From Equation (15) one obtains:

$$\frac{\partial \eta ST}{\partial \eta GT} < \frac{1-\eta GT}{1-\eta GT} \quad (16)$$

Improving the gas turbine efficiency is helpful only if it does not cause too great a drop in the efficiency of the steam process.

Table-4: Allowable Reduction in Steam process Efficiency as a function of Gas Efficiency (Steam process efficiency = 0.25).

η_{ST}	0.2	0.3	0.4
$\frac{\partial \eta ST}{\partial \eta GT}$	0.94	1.07	1.25

Table-4 Shows Maximum allowable reduction - $\frac{\partial \eta ST}{\partial \eta GT}$ as a operate of the turbine potency. This table indicates that the upper the potency of the turbine is also reduction in efficiency of the steam method. The proportion of the general output being provided by the turbine increase reducing the result of lower potency within the steam cycle. However a turbine with a most potency still doesn't give associate in nursing optimum combined cycle plant. For example-with a continuing turbine body of water temperature a turbine with a awfully air mass magnitude relation attains the next potency that a machine with a moderate pressure ratio. However, the potency of the combined cycle plant with the second machine is considerably higher as a result of the turbine that follows operates much more efficiency with higher exhaust gas temperature and produces a larger output. Table-2 shows the potency of the turbine alone as a operate of the turbine body of water and exhaust temperatures, the most potency is reached once the exhaust gas temperatures are quite low (A low exhaust temperature means that a air mass magnitude relation).

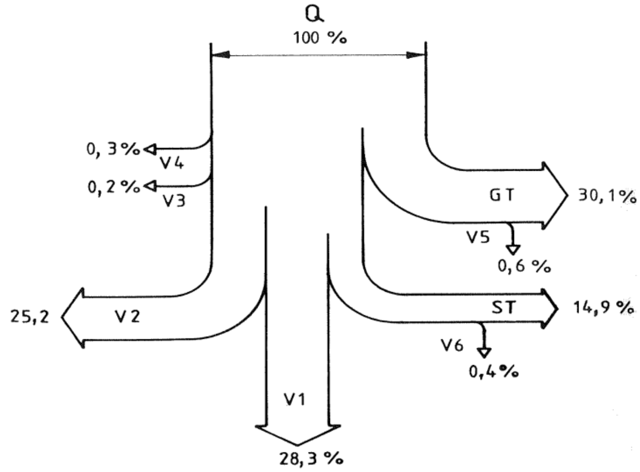

Figure-10: Energy flow sketch for combined cycle.
Q=Energy input, V_1=waste in condenser, V_2=waste in stack gases, V_3= waste due to radiation in waste heat boiler, V_4= waste in flue gas bypass, V_5= waste in generator and radiation, gas turbine, V_6= waste in generator and radiation, steam turbine, GT=Electricity created in gas turbine, ST=Electricity created in Stream turbine.

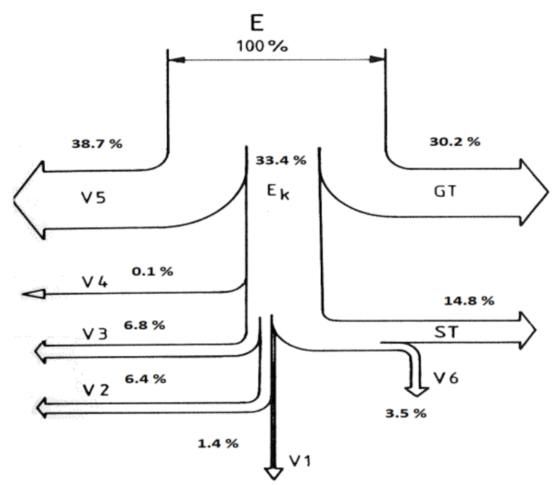

Figure-11: Exergy flow sketch of the combined cycle.
E =Exergy input, V_1= waste in condenser, V_2= waste in stack gases, V_3= waste in waste heat boiler, V_4= waste in flue gas bypass, V_5= waste in gas turbine, V_6= waste loss in steam turbine, GT=Electricity created in gas turbine, ST=Electricity created in Stream turbine, E_k= Exergy equipped to the waste heat boiler.

Results and Discussion

The results of the combined cycle powerhouse are shown in Tables-2 and are obtained. Once evaluating a plant, we have a tendency to primarily specialize in its avertible energy destruction, as a result of it represents the potential for improvement. The result shows that gas turbines have a standardized potency whereas compressors and combustion chambers are additional economical.

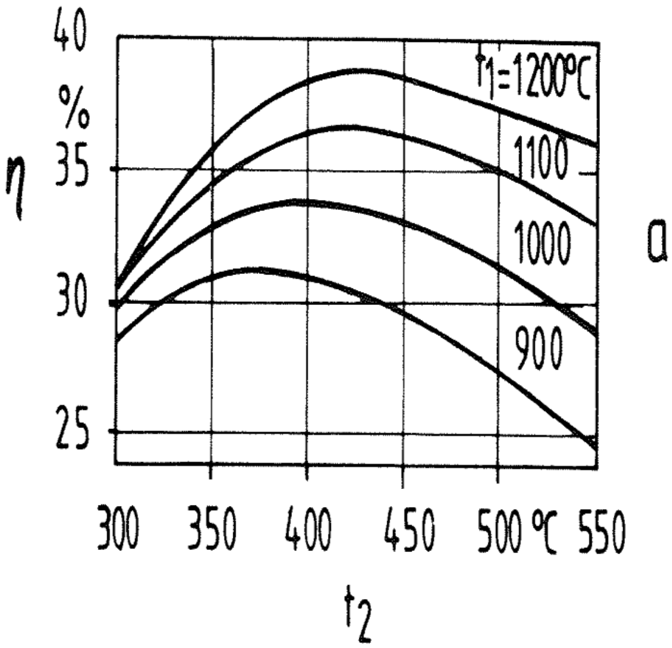

Figure-12: Gas turbine only.

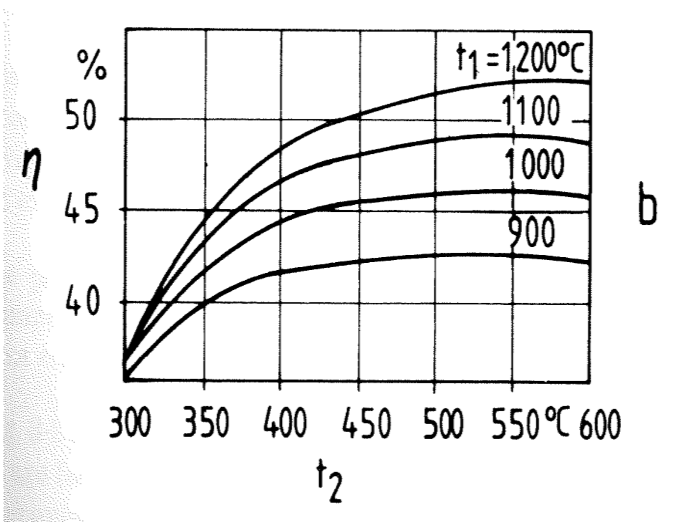

Figure-13: Combined cycle power plant.

Thermodynamics efficiency of gas turbine in combined cycle power plants (Function of the turbine inlet and outlet temperature). Where t_1=Gas turbine inlet, t_2 = Gas turbine exhaust efficiency: Gas turbines of a additional complicated style i.e with intermediate cooling within the mechanical device or recuperator are appropriate for combined cycle. We have a tendency to shall not discuss a heat up turbine here since this kind of machine has disappeared from the market thanks to its quality. The rotary engine water temperature could be a way more necessary issue. Similar issues conjointly apply with relation to the potency of the steam cycle. These, however are lesser as a result of the turbine is mostly the quality machine. The exhaust heat obtainable for the steam method is so a given, and the problem lies solely in its most conversion into energy.

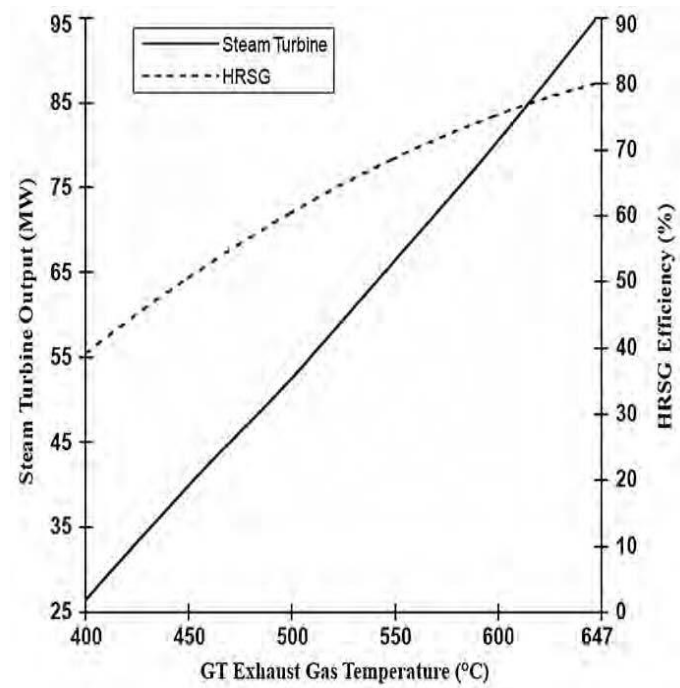

Figure-14: Steam turbine output Vs HRSG Efficiency.

Table-5: Main Technical Data of the single pressure Combined cycle plant.

Component	Quantity
Gas turbine output	67.8 MW
Steam turbine output	33.8 MW
Station service power required	1.2 MW
Net power output of plant	101.4 MW
Thermal energy supplied (diesel fuel)	227.0MW
Efficiency of gas turbine	29.6 %
Heat contained in Exhaust gases	156.4 MW
Utilization rate of waste heat energy	62.4 %
Efficiency of steam process	22.5 %
Gross efficiency of the plant	53.2 %

Net efficiency of the plant	52.3 %

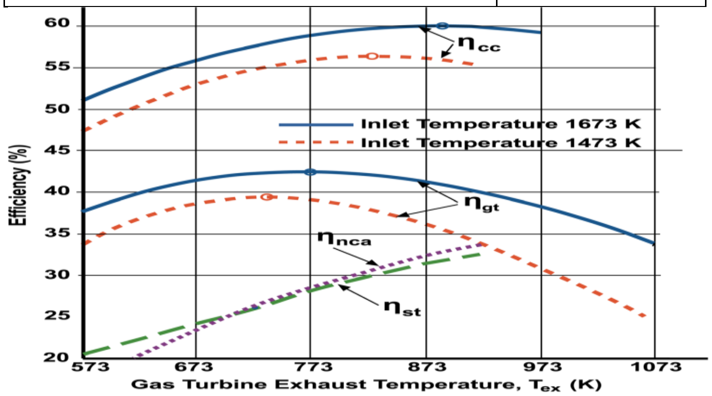

Figure-15: Steam turbine output and HRSG efficiency Vs gas turbine outlet temp for a singlr pressure cycle.

Conclusion

The Combined cycle power plants meet the growing energy demand and so special attention ought to be paid to the development of the full plant. The ability plant developments for chemical action of coal and use inside the rotary engine unit in advanced stages. However, the combined cycle is currently well established and offers optimum performance to any of the ability plant that are doubtless to be accessible within the medium term for giant scale power generation applications. This work contains associate improvement analysis of 4 potential cycles, namely i. Gas rotary engine, ii. Reheat turbine, iii. Steam turbine while not heat, iv. Combined cycle turbine power station. The planning purpose and off design point performances of the four cycles alone or together with the steam cycle are investigated. Leading to the turbine output is sixty seven. 8 MW, turbine output is thirty four. 8 MW. Steam cycle potency is twenty two. 5% and also the overall potency is fifty three. 2%. Internet power output of plant one zero one. 4 MW. Utilization rate of waste energy sixty two 4%. It's price mentioning that a fraction of condition of eight. 0% is way below the appropriate limit of 14%, that merely means that longer life for the installation. The full power output is a hundred MW.

References

1. India Energy Forum Power India (2005-06). Year Book.

2. Climate Change (2007). Synthesis Report. Available online: http://www.ipcc.ch/pdf/assessment-report.

3. Climate Change (2014). Mitigation of Climate Change, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

4. Yue Hu, Yachi Gao, Hui Lv, Gang Xu and Shijie Dong (2018). A New Integration System for Natural Gas Combined Cycle Power Plants with CO_2 Capture and Heat Supply.

5. Venkata Seshendra Kumar Karri (2014). A Theoretical Investigation of Efficiency Enhancement In Thermal Power Plants.

6. Rolf kehlhofer (1997). Combined-Cycle Gas & Turbine Power Plant. 12-56.

7. Polyzakis, A. L., Koroneos, C., & Xydis, G. (2008). Optimum gas turbine cycle for combined cycle power plant. *Energy conversion and management*, 49(4), 551-563.

8. Petrakopoulou, F., Tsatsaronis, G., Morosuk, T., & Carassai, A. (2012). Conventional and advanced exergetic analyses applied to a combined cycle power plant. *Energy*, 41(1), 146-152.

9. Kaviri, A. G., Jaafar, M. N. M., & Lazim, T. M. (2012). Modeling and multi-objective exergy based optimization of a combined cycle power plant using a genetic algorithm. *Energy Conversion and Management*, 58, 94-103.

10. Ameri, M., Ahmadi, P. O. U. R. I. A., & Khanmohammadi, S. H. O. A. I. B. (2008). Exergy analysis of a 420 MW combined cycle power plant. *International journal of energy research*, 32(2), 175-183.

11. J. H. Horlock (1998). Combined power plants-Past, present, and future. *ASME J. Engrg. for Gas Turbines Power*, 117 (4) 608–616.

12. P. J. Dechamps (1998). Advanced combined cycle alternatives with the latest gas turbines. *ASME J. Engrg. Gas Turbines Power*, 120, pp350– 357.

13. D.L. Chase, (2001). Combined-cycle. Development, evolution and future, Technical Report GER-4206, GE Power Systems, Schenectady, NY. 5-6.

14. Jericha, H., Fesharaki, M., & Seyr, A. (1997). Multiple evaporation steam bottoming cycle. In Turbo Expo: Power for Land, Sea, and Air. *American Society of Mechanical Engineers*, 78699, V002T08A006.

15. Schultz, R., & Bachmann, R. (1999). KA24-1CST—Market success for a standardized power plant. Report M489, ABB.

16. C. Casarosa and A. Franco (2001). Thermodynamic optimisation of the operative parameters for the heat recovery in combined plants. *International J. Appl. Thermodynamics*, 4, 43–52.

17. C. Casarosa, F. Donatini and A. Franco (2001). Thermoeconomic optimization of HRSG operative parameters for combined plants. *Proceedings of the ECOS Conference*, Istanbul, Turkey, 2, 801-812.

18. V. Ganapathy (1994). Steam Plant Calculation Manual, Marcel Dekker, New York. 1994-452.

19. Kotas, T. J. (1995). *The Exergy Analysis Method of Thermal Plant Analysis*. Krieger. Melbourne, Australia.