EXERGY ANALYSIS OF VARIOUS PARTS OF DUAL CYCLE POWER PLANT WITH ORGANIC RANKINE CYCLE AND ABSORPTION REFRIGERATION SYSTEM

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CANDIDATE'S DECLARATION

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ABSTRACT

The performance of the thermal power station is evaluated through effective performance standards, which is mainly based on the 2nd law of thermodynamics, along with thermal efficiency. Actual loss of useful energy can’t be determine by the applying 1st law of thermodynamics, because it does not differentiate between quality and quantity of energy. Exergetic analysis gives the tool for fair separation between energy losses that occur to the environment and all internal irreversibilities in the process. The effectiveness of exergetic analysis is used to determine magnitudes, location and causes of irreversibilities in the plants, as well as it also gives more meaningful estimate of individual efficiency of plant components. In this analysis of combined cycle integrated with Organic Rankine Cycle and Vapour Absorption Refrigeration System, large losses takes place in the combustion chamber and exergy destruction is also displayed in different parts of the power plant. There are two important criteria in the exergetic analysis: efficiency and exergy destruction. An important application of the exergetic efficiency is the evaluation of the dynamic thermal performance of component or system related to a similar performance. The results exhibit that the highest exergy loss occurs in combustion chamber of the gas turbine, is due to its very high irreversibility. Since the second greatest loss in plant takes place is in HRSG, the optimal use of HRSG will play a crucial role for decreasing the exergy loss of the combined power plant. The results demonstrate that the combustion chamber, along with heat recovery steam generators (HRSG) and gas turbines are key sources of irreversibility. Exergy losses in different vitality components of the power plant have been observed and improved relatively well by using Organic Rankine cycle and vapour absorption cycle. The improvement in these components provides a wide space of improvement for researchers and academicians in the power plant.

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C_p	Specific heat
ST	Steam turbine
GT	Gas turbine
$\dot{I}$	Rate of exergy loss
$\dot{Q}$	Rate of heat transfer (kW)
$\dot{W}$	Work rate (kW)
$\dot{ED}$	Exergy destruction rate (kW)
$\dot{X}$	Exergy rate (kW)
$\dot{X}^Q$	Rate of thermal exergy flow rate (kW)
$\dot{m}_r$	Mass flow rate of refrigerant (kg/s)
T	Temperature (K)
S	Specific entropy (kJ/kg-K)
H	Specific enthalpy (kJ/kg)
Comp	Compressor
Comb	Combustor
HRSG	Heat recovery steam generator
Exh	Exhaust
ORC	Organic Rankine Cycle
OLE	Organic liquid evaporator
OVT	Organic vapour turbine
OLFP	Organic liquid feed pump
OVC	Organic vapour condenser

CHAPTER 1

INTRODUCTTON

1.1 OVERVIEW

World's population increment and considerable general financial improvement are causing the expansion sought after for vitality drastically. The vitality supply has go through stun because of financial emergency that has delivered the worldwide market. The hole between vitality free market activities has risen consistently. Studies demonstrated that there was an estimated 6% normal yearly development in the power interest for the world. Furthermore, a climb sought after for the vitality expected in coming years.

The expanded sharpness of the constrained vitality assets of world have effectively affected numerous nations as in the most of them have enthusiastically re-evaluated their approaches for the vitality and have likewise taken radical measures for takeout waste

Vitality utilization is a standout amongst the most essential pointer demonstrating the improvement phases of nations and expectations for everyday comforts of networks. Increment in vitality utilization are because of the a few factors, for example, populace increase, urbanization, industrializing, and innovative advancement. This quick developing pattern gives disturbing sign about the genuine natural issues, for example, tainting of ground water and nursery impact. Presently a days, around 80% of aggregate power of the world is created by non-renewable energy sources, (for example, coal, oil, flammable gas, fuel-oil) in terminated warm power plants, while vitality from various sources i.e. water powered, wind, atomic, sun oriented, biogas, and geothermal full filled 20% of the aggregate power. By and large, first law of thermodynamics was utilized for acquiring the execution of warm power plants in light of lively execution criteria, including warm productivity and electrical power. From last a few decades, second law of thermodynamics is begun for acquiring the exergetic execution and it has been found as helpful strategy in the assessment, outline, advancement and change of warm power plants. Additionally scientists are occupied with utilizing both, first and second laws of that thermodynamics to make sense of the effectiveness of exergy and exergy annihilation by which the accessible vitality is devoured. Exergetic examination gives the device for reasonable detachment between vitality misfortunes that jump out at nature and every single interior irreversibility simultaneously. The viability of exergetic investigation is utilized to decide sizes, area and reasons for irreversibilities in the plants, and in addition it additionally gives more significant gauge of individual effectiveness of plant segments. The second law of thermodynamics derives the concept of exergy, which always decreases due to thermodynamic irreversibility. In order to define exergetic efficiency, it is necessary to identify both product and fuel for the thermodynamic system being analysed. The product represents the desired effect produced by the system; the fuel represents the resources expended to generate the product. Both fuel and product are expressed in terms of exergy. [1].

Henceforth, these are the reasons, exergy examination is utilized for present day approach to process investigation, this gives a superior practical perspective of all the procedure and it turns into a valuable device for assessment in building. All things considered, numerous specialists prescribed exergy examination for basic leadership about assets portion (capital, enhancement, innovative work exertion, materials, life cycle investigation and so on.) as opposed to vitality investigation. Exergy examination turned into a most valuable component that gives a superior judgment of the procedure, distinguish the wellsprings of wastefulness, and to separate nature of vitality utilized.

Conventional exergetic, exergoeconomic and economic analyses establish accurate interpretation of conversion of energy systems. Exergetic analysis by conventional method, we can know about the irreversibilities of each component of a power plant.

1.2 POWER PLANT

The power plant is a mix of frameworks or subsystems for producing power, i.e. vitality, economy and necessities. The power plant must be financially helpful and earth amicable to our general public also. Notwithstanding the fundamental spotlight on the vitality sparing framework, with respect to conventional vitality frameworks, particularly to enhance the productivity of framework change, the principle objective is the advancement, outline and generation of capricious power plant in the coming decades, ideally around 2050 AD. Great to the network and furthermore has productive vitality transformation is appropriate and contamination free, considering contamination enactment [3].

Industrial changes have contributed for growth of electric power, which soon became an important factor for humans. The desire to prepare for electricity has been growing rapidly, and it has the power to increase its power. A part of material is changed due to the capacity of heat. For instance, heat changed a solid material into fluid and fluid into vapour.

1.3 CLASSIFICATION OF POWER PLANTS

There are two types of Power plants: One is conventional and another is non-conventional.

1.3.1 Conventional Power Plants: All the sources of energy which have been in use since a long period time for example, coal, oil, natural gas and hydroelectricity. The energy used since ancient times is called conventional energy. Coal, oil, natural gas and wood are examples of traditional energy sources. The sources of energy (i.e. electricity) are wood, coal, oil, peat, uranium.

1.3.2 Non-Conventional Power Plants: Resources that have been developing during the last years. These include solar, wind, tidal, biogas, biomass and geothermal. Non-conventional sources will become traditional or conventional and common, and every day, because they are all green, free, and emitted by carbon dioxide (as biomass does, but they avoid producing of methane gas, which is 21 times more dangerous than carbon dioxide).

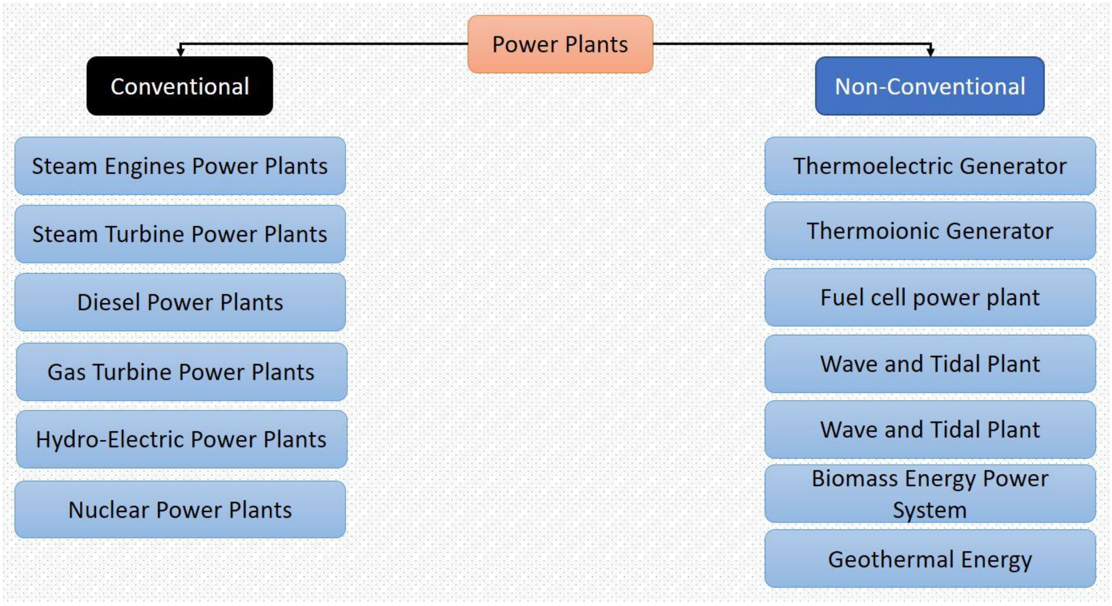

Figure: 1.1 Classification of various power plants

1.4 CURRENT SCENARIO OF POWER PLANTS IN INDIA

India's present position of intensity is disturbing, as there is a huge power deficiency in relatively every stage in the nation, which causes the interruption of enterprises, a great many individuals losing their employments and an extensive loss of creation. The general vitality display of the nation demonstrates a critical lessening in every one of the stages. The circumstance will decrease in the coming a long time as request increments and the vitality business does not stay aware of the developing interest. Numerous stages in India depend intensely on the age of hydroelectric power. The expansion popular has incredibly surpassed the establishment of new plants. Nor is there a focal system to disseminate overabundance vitality starting with one area then onto the next. The involvement in working warm plants is inadequate. This prompted genuine deficiencies and genuine troubles for individuals. An exceptionally total examination of the issue and appropriate arranging and usage is fundamental to unravel the vitality emergency in our nation. Blend of sufficient warm water, the right application for the development of new plants, preparing of staff in the support of warm establishments.

1.5 FORTHCOMING POWER PRODUCTION IN INDIA

As indicated by the present government arranging, the issue of expanding vitality request will be explained just by the sufficient blended improvement of hydroelectric, heat and atomic energy, in any event in one more decade. The issue of vitality can be comprehended to some extent by monitoring vitality. Production of electricity by thermal power plant not very high and 35% is its efficiency. In India, it is very nearly to 25%. On the off chance that the extra utilization and line misfortune are considered, the effectiveness stays at 16%. The issue can be incompletely settled with legitimate upkeep and a supply of good quality fuel.

The proficiency of the task of the power plant is likewise characterized as the Kw/hr created per unit kW introduced. The most extreme kWh every year per kW is 8760. The normal figure in India is very nearly 4000, which demonstrates that exclusive 45% utilize it. On the off chance that this utilization is expanded, the need to incorporate the new power age limit will be lessened. The expansion in stack variables can lessen the limit of the vitality business. Sufficient making arrangements for the advancement of India's water, electrical, warm and atomic assets, and in addition measures to decrease intrusions and appropriate load administration, would go a more drawn out path looking toward meeting the nation's developing vitality request.

Worldwide vitality needs solid non-renewable energy sources to create power. The greater part of the power age on the planet is provided with non-renewable energy sources, especially coal and gaseous petrol. In spite of the development of sustainable power source offices, i.e. sun powered and wind, petroleum products are anticipated to remain profoundly subordinate for a very long while. Despite the fact that the diminishment of all non-renewable energy source holds and furthermore ecological concerns i.e. environmental change, the expansion in oil request is relied upon to be 47.5 percent in the vicinity of 2003 and 2030, 91.6 percent for flammable gas and 94.7 percent for coal. Despite the fact that cleaner sustainable power sources are growing quickly, their relative cost and current mechanical stage have not advanced to a phase where they can without a doubt diminishing our reliance on petroleum derivatives. In this way, given the proceeded with reliance on petroleum derivatives, it is noticed that some time non-renewable energy source plants diminish their effect on condition by working productively [4].

1.6 BASICS OF EXERGY ANALYSIS:

1.6.1 Thermodynamic Analysis

We can defined thermodynamics as energy science. It is the study of energy interactions between systems and the effect of these interactions on the characteristics of the system. Energy is moved between frameworks in type of heat and work. For thermodynamic investigation, the first and second laws are utilized at the same time.

1.6.2 First Law of Thermodynamics

The 1st law of thermodynamics, it otherwise called the principle of energy protection, gives a strong premise to knowing the connections between various types of energy and energy associations. The 1st law of thermodynamics expresses that power can't be created or vanished amid the procedure, models must be changed. In this manner, each part of the power must be figured amid the procedure.

$$(Total\ energy\ entering\ the\ system) - (Total\ energy\ leaving\ the\ system)$$
$$= (Change\ in\ total\ energy\ of\ the\ system)$$

Or,

$$E_{in} - E_{out} = \Delta E_{system}$$

Energy balance equations for closed and steady flow system are given as below:

(i) Energy balance for closed system:-

$$Q_{net,in} - W_{net,out} = \Delta E_{system}$$

Or,

$$Q - W = \Delta E$$

Where, $Q = Q_{net,in} = Q_{in} - Q_{out}$ is the heat input, $W = W_{net,out} = W_{out} - W_{in}$ is the net work output.

- $Stationary\ System$: $Q - W = \Delta U$
  $As, \Delta KE = 0,\ \Delta PE = 0\ and\ \Delta U = 0$
- $Per\ unit\ mass$: $q - w = \Delta e$
- $Differential\ form$: $\delta q - \delta w = de$
  $System\ undergoing\ cycle$: $Q - W = 0\ or\ Q = W$ (initial and final points are same)

(ii) Energy balance for Steady-Flow system:-

Steady-flow process is the procedure amid which liquid courses through a control volume consistently.

$$Mass\ Balance: \sum \dot{m}_{in} = \sum \dot{m}_{out}$$

1.6.3 Second Law of Thermodynamics

The 2nd law of thermodynamics, affirms that procedures happen in a specific way and that energy has both a quality and an amount. The procedure is impossible except if both the first and second law of thermodynamics are met. The second law of thermodynamics is the law of constraint. It can be accustomed to getting the hypothetical furthest reaches of the execution of by and large utilized building frameworks, i.e. iceboxes and warm motors, and additionally to foresee the level of chemical reaction finished.

1.7 EXERGY ANALYSIS

Exergy can be characterized as the greatest valuable hypothetical work that can be accomplished when the framework consolidate with the balance stage. Sun powered energy isn't generally put away as energy, yet is annihilated in the framework. For the design, optimization and for performance evaluation, the Exergy analysis becomes a dynamical tool in the energy systems. Exergy balance applied to an entire process or plant tells us about the amount of viable potential, or the Exergy that is provided as input to the system under study (irreversible loss) is used by the process. The exergy or irreversible destruction provides a quantitative measure that is generally applicable for an inefficient operation. The multivariate analysis of plants refers to the distribution of the aggregate irreversibility of the plant among the components of the plant, which determines which contribute more to the inefficiency of the plant in general [5]. The Exergy investigation is valuable to enhance the proficiency of the utilization of energy asset, since it locates the types and amount of losses.

1.7.1. Exergy Destruction (ED)

Irreversibilities for example, chemical reactions, friction, mixing, heat exchange through constrained temperature varieties, unrestricted expansion and un-semi-balanced pressure or expansion dependably leads to the generation of entropy, and everything which generates entropy always destroys stress. For any real process, exergy is destroyed as a positive quantity and it becomes zero for the inverse operation. Exergy is the capability of lost work and is likewise called irreversibility or loss of work.

1.7.2. Total Exergy Destruction

This is the aggregate decimation of the exergy in various parts of the framework. The second law of thermodynamics gives an approach to allot a record of energy quality. The exergy idea gives a valuable estimation of the nature of vitality. The effectiveness of the second law or publication productivity and it is characterized as, proportion of least exertion required to play out an offered assignment to the real pressure expended in playing out a similar undertaking [6].

1.7.3 Exergetic Efficiency

It is also called 2nd law of Efficiency. The 2nd law of Efficiency or exergetic efficiency, is a useful tool in evaluating the true thermodynamic performance of a particular system because it indicates how much of the available energy is translated to useful work.

$$\eta_{exergetic} = \frac{Total\ rate\ of\ exergy\ output}{Total\ rate\ of\ exergy\ input}$$

CHAPTER 2

LITERATURE REVIEW

The investigation of a power plant is a wide idea that incorporates utilization of vitality assets productively. In the past time, the vitality proficiency of the plant was broke down in view of the first law of thermodynamics. Be that as it may, as of late, the second law of thermodynamics has been broadly used to decide pressure misfortunes since it is straightforwardly identified with the nature of the vitality created inside the framework.

Arora B. B et al. [7] done energy and exergy analysis of engine exhaust driven vapour absorption refrigeration system. It is done on series flow triple effect water-lithium bromide (H_2O-LiBr) absorption system and engine exhaust is used as a heat source for this system. A computational model has been developed and effect of generator and absorber temperature on the energetic and exergetic performance of the system is found.

Abuelnuor A.A. et al. [8] gave an analysis of the combined cycle power plants "Garri 2", which produces around 180 MW. In order to finding energy efficiency and destroy every component, an observation of the existence of "Garri 2" was carried out and an exergy and energy balance was analyzed to achieve it. Fundamentally, the results have shown that combustion chambers are the main sources of bone energy destruction due to their non-cut height. These results illustrate in detail the beneath percentages: 63% of the total destruction of external forces, by gas turbines 13.6%, by steam turbines 6.4%, by HRSGs 6.3%, by flue gases 4.7%, by compressors 3.8% and 2.3% by chilling medium. In addition, the outcomes arranged that warm productivity for plant is 38% while exergetic efficiencies for the plant is 49%.

Regulagadda et al. [9] done a thermodynamic investigation of non-basic gas turbine generators for a 32 MW electricity plant. The two mixes of intensity and exergy are produced for the framework. Parametric investigation of the power plant was completed with various working conditions, for example, extraordinary working pressure, diverse working temperatures and furthermore unique stream rates, for deciding the distinctive parameters that expansion the effectiveness of the power plant. From the analysis of the power plant, it was determined that the efficiency is of 30.16% of the total production.

The eclair efficiency of the plant was 25.38%. The maximum destruction of exergy in the boiler was found. It is also reported that the efficiency of boiler is improved for improving the efficiency of the plant.

Oko and Njoku [10] given execution examination of a joined steam power plant of gas, steam and natural (IPP). The consolidated cycle control plant is predominantly in view of the utilization of waste warmth from a 650 MW joined power plant to work the ORC. The outcomes exhibit that extra 12.4 megawatts of intensity were created from the ORC warm unit. The productivity and vitality thickness of the CCPP enhanced with the present effectiveness of CCPP at 1.95 and 1.93%, individually.

Ahmadi, Dincer, and Rosen [11] have actualized the vitality, fatigue, exergoeconomics, ecological enhancement and multi-utilization of a coordinated multi vitality framework in light of the utilization of waste warmth from a petroleum gas turbine control plant to work the cycle of steam turbines. Refrigerant ingestion, cyclic cooling/lever Rankin natural, nearby radiator and parasitoneal analyser, for creation of synchronous vitality, warming, cooling, high temp water and hydrogen.

Mohapatra [12] compared the effect of CCPP by the integration of the refrigeration system with the vapour pressure and the refrigeration system through the absorption of steam in a combined cycle power plant for internal cooling. Its work revealed that by cooling of inlet air, vapour pressure compression increased the nominal power output 9.02% as compared to the 6.09% obtained with the vapour absorption cooling. However, for operating the VCRS, the energy is extracted from the output of the gas turbine.

Ibrahim T.K. et al. [13] evaluated the most recent thermodynamic investigation of every last part of the CCPP framework autonomously and decided the gigantic pulverization of the plant. Some CCPP plant outlines from various areas are considered contextual analyses. Truth be told, a large portion of the vitality misfortunes happened in the condenser contrasted with the fixings in the plant. I found that the best demolition of exergy happened in burning chamber (CC). The surrounding temperature prompts a noteworthy lessening in vitality creation by the gas turbine (GT). The outcome has been that, alongside vitality, stretch investigation is a powerful method to assess the execution of CCPP by prescribing a more helpful design of CCPP, prompting decreases in required fuel and emanations of air toxins. Among the CCPP framework, the HRSG framework has an imperative wellspring of decimation of bone vitality because of the compound cooperation between the packed air and the fuel channels. The primary factors that influencing, the overabundance air portion exist in the ignition chamber and air channel temperature. Improvement can be accomplished by lessening the air-fuel proportion and preheating the burning air.

Vidal A. et al. [14] proposed a new joint cycle to simultaneously produce energy and cooling with a single source of heat and the use of mixtures of water and ammonia as working liquid. The simulation of the session was implemented in the ASPEN Plus process emulator. The course was simulated as reversible, as well as irreversible process to show the effect of irreversibility in each and every component of the course.

The method of stress analysis applied to a new cycle illustrates its ability to produce both energy and cooling by applying low temperature heat sources. However, the resulting cooling is small compared to the energy generated. With reference to the system proposed by Goswami, the session was analyzed and some important specific points were changed, such as the atmospheric temperature, the turbine efficiency and also rectifier’s temperature. The stress indicators were good indicators to show the effectiveness of the cycle, as well as to identify the devices in which most of the destruction occurs. Although non-reversible cycles are a large generation of entropy, there is a high potential for improvement, which means that the use of optimization techniques can be reduced and the general reversibility of the course is possible.

Kaushik S.C. et al. [15] examination Most power plants are planned by dynamic execution norms construct basically in light of the first law of thermodynamics as it were. The loss of valuable genuine vitality can't be legitimized by the law of thermodynamics, since it doesn't recognize the quality and the amount of vitality. In this examination, the correlation between vitality investigation and the discharges of coal and gas warm power plants. The Exergy investigation shows up in this article assist us with understanding about the execution of coal and coal control plants and distinguish conceivable outline efficiencies. It gives a legitimate answer for enhance the conceivable outcomes of vitality generation in warm power plants. Through the exergy examination it can be presumed that the fundamental vitality misfortune in the evaporator in the coal-let go thermoelectric influence station and the burning chamber in the joined warm influence plant consolidated the let go gas. Obviously, in each component of the plants, for example, the evaporator, there is a burning chamber; there is a self-decentralization that, because of the current mechanical circumstance, can't be dispensed with. Moreover, stretch strategies are valuable for assessing the enhancements they merit and it ought to be utilized as a part of union with other applicable data to control proficiency change endeavors for steam control plants.

Petrakopoulou F. et al. [16] Examined the consolidated cycle of the power station utilizing all regular and furthermore progressed exergetic investigation. Except for the extension of the gas turbine frameworks and the high weight steam turbines, a large portion of the annihilation that happens in the parts of the plant can't be kept away from. This inescapable part is confined by interior mechanical limitations, that is, the pulverization of the exergy of every component. The best devastation of obliteration happens by CC.

Aljundi I.H. [17] investigated vitality and exergy investigation at the Al Hussein control station in Jordan. They dissected the parts of the framework independently and recognized the area of the locales with the best loss of vitality and exergy. What's more, the impact of changing the reference condition will likewise be exhibited in this examination. The execution of the power plant was assessed by prudent demonstrating of the segment and itemized subtle elements of the vitality and misfortunes to the plant were given. The vitality misfortunes happened for the most part in the condenser, albeit 134MW lost in nature, and just 13 MW of evaporator framework was lost. The heater is the main wellspring of irreversibility in the entire power plant. Concoction reactivity is the most vital wellspring of obliteration of sun powered vitality in a kettle framework that can be diminished by preheating the burning air and furthermore by lessening the air-fuel proportion.

Arrieta F.R.P. et al. [18] concluded that operations of the combined cycle thermal power plant are dependent on the conditions of the region where it is installed, especially the ambient temperature, the atmospheric pressure and the relative humidity of the air. These guidelines affect the electrical energy generated and the operating temperature. Amidst these variables, the ambient temperature induced the greatest variation in performance during the operation. The plant selected for this study consists of a multi-column configuration consisting of two gas turbines Siemens Gas 501F, three HRSG and a reheating with additional combustion and a steam turbine.

Adibhatla S. et al. [19] analysed Energy, exergy and Economic Analysis (3E) performed on theoretical energy cycle formed by the integration of solar energy in the steam cycle of the Combined Cycle Generated Cycle Power Plant (CCPP). Solar energy has been integrated into the average temperature level by direct steam generation (DSG) technology with parabolic trough collectors.

The results showed that energy efficiency and exergy efficiency in the field of solar energy is 53.80% and 27.40%, respectively. The results showed that the production of the plant increased by 7.84% with the operation of the solar field by considering the design point to obtain a nominal capacity of 50 MW. The reduced cost of electricity generation was observed from 7.4 to 6.7% / kWh. The stress analysis revealed that the solar field has a 27.4% less effective efficiency among all ISCCPP DSCC components.

Verkhivkar G.P. et al. [20] investigated the execution of an ordinary power plant in light of the exergy idea. Quantitative examination of exergy annihilation demonstrated that the fundamental refractions were identified with the substance transformation of exergy to warm, ensuing exchange of this warmth to the working liquid and warmth trade in the net radiators. A diminishment in the pulverization of exergy was found by expanding the thermodynamic parameter of the turbine's working liquid and by decreasing temperature varieties in net warmers. To enhance warm outline and ideal method for the atomic power plants, it was proposed to completely evaluate the productivity of the atomic plant in light of coefficient of execution of framework.

Ibrahim T.K et al. [21] proposed several configurations of gas turbine plants by thermal analysis. An integrated model and simulation code was developed to exploit the performance of gas turbine plants using the MATLAB code. The performance codes for the heavy-duty GT power plants with the Basile model were validated and the results were satisfactory. The results of the performance improvement strategies show that there is a greater production of energy in the GT radiator strategy (IHGT) (286

MW). When compression ratio became 12.4 in the refrigerant (IRHGT), the highest efficiency (thermal) obtained was 50.7%. In IHGT, the minimum thermal efficiency recorded was 22% and 39.3% when pressure ratio varies between 3 and 30. Less fuel consumption (0.14 kg / kWh) found in the IRHGT strategy. Therefore, compression ratio are strongly affected by the whole performance of the gas turbine.

Rosen A M et al. [22] investigated the impacts of vitality and exergy examination from contrasts in the attributes of the dead stage, which incorporate two primary assignments: (1) to inspect vitality affectability and exergy esteems to choose properties of the dead stage and (2) break down the affectability of the consequences of the vitality examination. A contextual investigation of a coal control plant is to show the genuine effects. The outcomes demonstrates that the vitality sensitivities, exergy qualities, vitality and exergy examination results to slight varieties in the attributes of the dead stage are sufficiently little with the goal that the discoveries, conclusions and proposals in light of these investigations are not fundamentally influenced by property contrasts. It is demonstrated that despite the fact that the estimations of vitality and exergy rely upon the extraordinary attributes of the dead stage, the main aftereffects of vitality examination and exergy are not generally exceptionally touchy to sensible changes in these properties. In some outrageous cases, for example, a rocket that hops from ground level and flies into space, an exact vitality appraisal and watchful pressure esteems are required in light of the fact that the distinctions in the properties of dead stage are critical. For the genuine qualities of the dead stage, productivity, which is a levelheaded measure of a perfect approach and key explanations behind the wastefulness of the procedure, is just decided in a way predictable with exergy investigation.

Rostamzadeh H et al. [23] It performs dynamic analysis of thermal and economic cycle proposed through different working liquids, which shows that between all Aloessobuhtani fluid. In addition, multiple objectives are performed to improve the proposed cycle considering the pressure generator and the pressure heater and the temperature of the covariable resolution evapourator and the temperature condenser, using a genetic algorithm (GA). The improvement results showed that the course work proposed in an ideal case based on the functions of the specified destination when the generator and the geyser pressure and the temperature degree of the evapourator and the temperature of the condenser are pressed at 3 megapixels and 1 MPa and 280 K and 299.8 K, respectively, Aloessobotan are also used.

Wang J. et al. [24] another joined cycle of cooling and ingestion of the ejector, which consolidates the Rankin cycle and the cooling cycle of the ejector's retention, has recommended that both the yield and the cooling yield can happen at the same time. This consolidated course, which rises up out of the course proposed by the creators above, offers an ejector between the rectifier and the condenser, giving better execution without incredibly expanding the multifaceted nature of the framework. A farthest point investigation is done for finding the impacts of the fundamental thermodynamic basis on the execution of cycle. The temperature of the warmth source, the temperature of the condenser, the temperature of the evaporator, the gulf weight of the turbine, the temperature of the channel of the turbine and the smelling salts convergence of the essential arrangement significantly affect the creation Net vitality, cooling generation and vitality proficiency in the composite cycle. Plainly the ejector can enhance the execution of the joined session beforehand proposed by the creators.

Kang Q. et al. [25] He displayed a hypothetical structure for the vitality investigation of a sun powered vitality station incorporated in a tube, with hybridization, with pneumatic breeze turbines and the lower steam mass. From the investigation of the impacts of essential outline guidelines on vitality productivity, the warmth exchange effectiveness of preheating pre-warming is of most extreme significance to expand the commitment of sunlight based vitality to the half and half idea, while vitality proficiency increments through the ideal turbine for the air cycle in Brighton. Activity (basically through the pressure proportion, underneath the working temperature). The general productivity for this idea differs from around 40% when utilizing just Brighton low and high weight turbines, to over 48% in the idea of completely incorporated air vapor.

Karthikeyan et al. [26] Give vitality adjust to a steam generator to recover a level of warmth. Talk about exact focuses and methodologies on the age of steam and furthermore on the temperature profiles through the warmth recuperation steam generator. In this framework, it additionally closes the impact of the working conditions on steam creation and furthermore while talking about the temperature of the gas outlet of the steam generator to recoup the warmth. He likewise examined that the low-point squeeze comes about is improved warmth recuperation steam generator execution in view of low irreversibility. Then again, he additionally talked about that supplemental fire expands steam generation.

Zhao et al. [27] performed examination demonstrate for the vehicle cycle of the gas turbine with the coke stove gas as per the real business arranging. The exergy examination is performed for particular work conditions to give a manual for viable task in the business. The warm productivity is higher than the exergy effectiveness. The general framework's warm productivity is 71.42% and the exergy proficiency is 62.46%. It might mirror the situation of vitality use.

Sahin et al. [28] examined the vitality and the exergy of the Atlas Iskenderun control plant. The plant is intended to work in supercritical steam conditions with a yield of 600 MW. The vitality and exergy stream rates and the efficiencies of each part were acquired utilizing the IAPWS-IF97 plan and the thermodynamic conditions. The vitality and exergetic proficiency of the supercritical power plant were found under assessed working states of 44.17% and 40.83%, individually. It was acquired that a large portion of the exergetic misfortune occurs in condenser at 659.16 MW and the vast majority of the release misfortune occurs in the evaporator at 761,097 MW. Accordingly, to improve the adequacy of the power plant, evaporator's execution ought to be enhanced, as this will bring about the best change in the effectiveness of the plant. It was additionally announced that the exergetic proficiency of the power plant diminished if there is an expansion in the encompassing temperature regarding the reference. It has been discovered that an expansion of 1 ° C in the natural encompassing temperature caused a diminishing of 0.14% in vitality proficiency and the exergy productivity diminished by 0.12% of the power plant.

2.1 LITERATURE GAP

After going through several literature survey in the area of proposed work, it is found that-

- Very few work is available on combined cycle integrated with Organic Rankine cycle and Vapour absorption refrigeration system. No one did exergy analysis of combined cycle integrated with Organic Rankine Cycle and Vapour Absorption Refrigeration System.
- Exergy is better parameter to measure losses in the combined cycle power plants with respect to energy.
- Main energy loss occurs in condenser and major exergy destruction occurs in combustion chamber.
- Among the all systems of the CCPP Heat Recovery Steam Generator (HRSG) has primarily remarkable sources of exergy destruction because of the chemical reaction between compressed air and fuel input. The main factor that affecting the excess air fraction exist in the combustion chamber and air inlet temperature.
- The ambient temperature and the operational condition of the CCPP strongly affect their performance.
- It has been also found that efficiency of power plant increases if we use ejector refrigeration system and solar power plant in place of gas turbine in CCPP.

2.2 OBJECTIVE OF PRESENT WORK

- The objective of this type of approach is to use all of the heat energy in a power system at the different temperature levels such as in Organic Rankine cycle and Vapour absorption refrigeration system, at which it becomes available to produce work, or heating of air or heating of water, or steam, therefore rejecting a minimum of energy waste.
- Calculating the exergy losses in various component in power plant and find that where is the maximum exergy loss occurred.
- Also all the benefits are determined after integrating combined cycle with Organic Rankine cycle and Vapour absorption cycle.
- The influence of reference environmental temperature on Irreversibilities and the efficiencies of power plant have been investigated.

CHAPTER 3

METHODOLOGY

3.1 COMBINED POWER PLANT CYCLE SYSTEM:

The combined power generation plant is utilized with cogeneration innovation that utilize energy along with heat from a solitary fuel source or power source in the meantime, and can give a more productive power production framework.

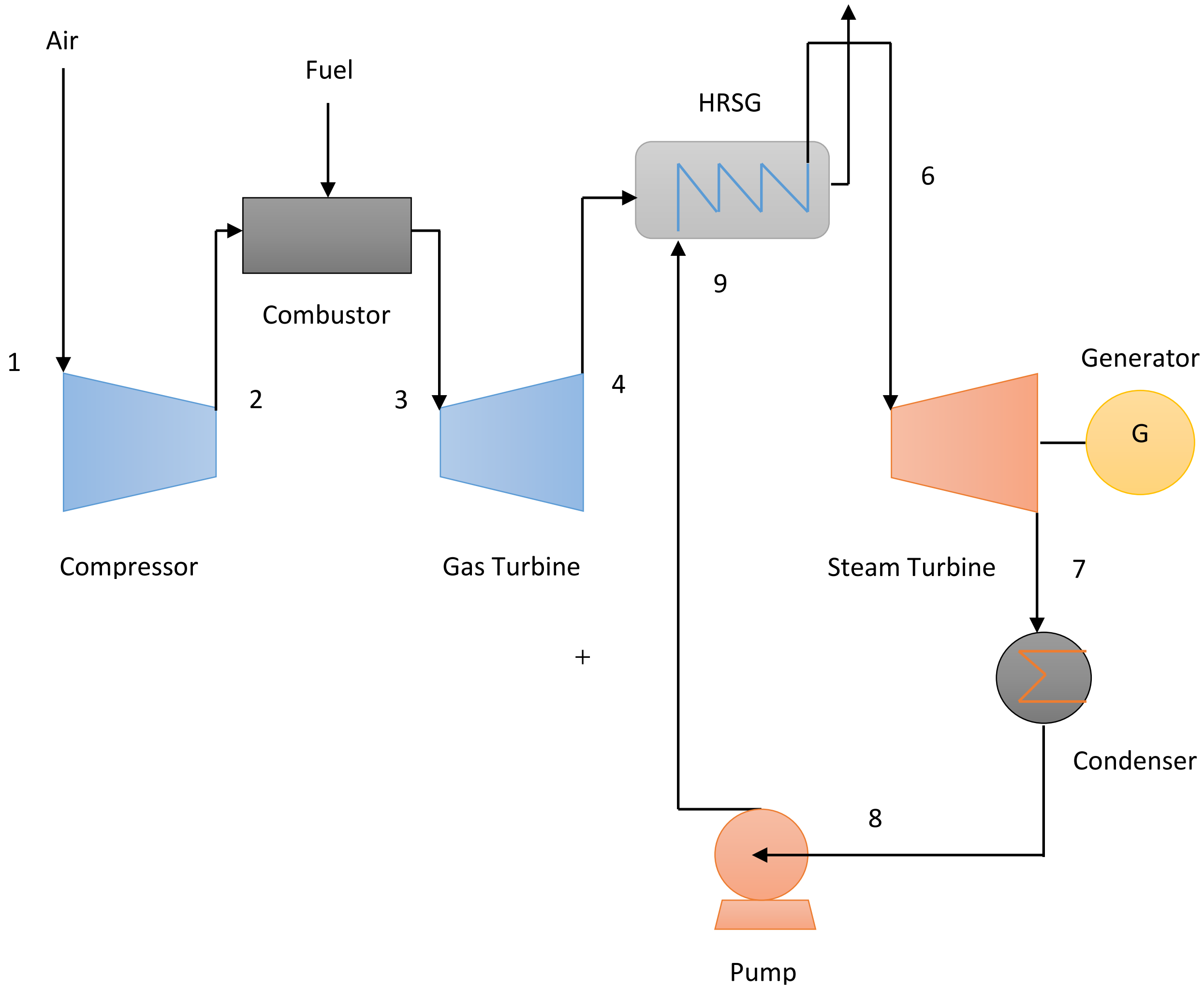

Figure: 3.1 combined cycle process

Figure 3.1 shows a set of open cycle gas turbines and steam turbines. Exhaust gas turbines with high oxygen content. High temperature flue gases from the gas turbine power plant provides heat to thermal power plant. This heat is utilize to produce steam in the boiler. Therefore, the steam generator is used for operating steam turbines. The combination of two and more than two thermodynamic cycles improves overall efficiency, reducing the cost of fuel in fixed plants. The very commonly used form is the gas turbine (operated in the Brighton cycle) where natural gas or synthetic gas is obtained from coal, through which the thermal power plant operates (working on the Rankine cycle). It is known as joint gas turbine plant (CCGT).

3.2 T-S DIAGRAM FOR COMBINED POWER PLANT CYCLE SYSTEM:

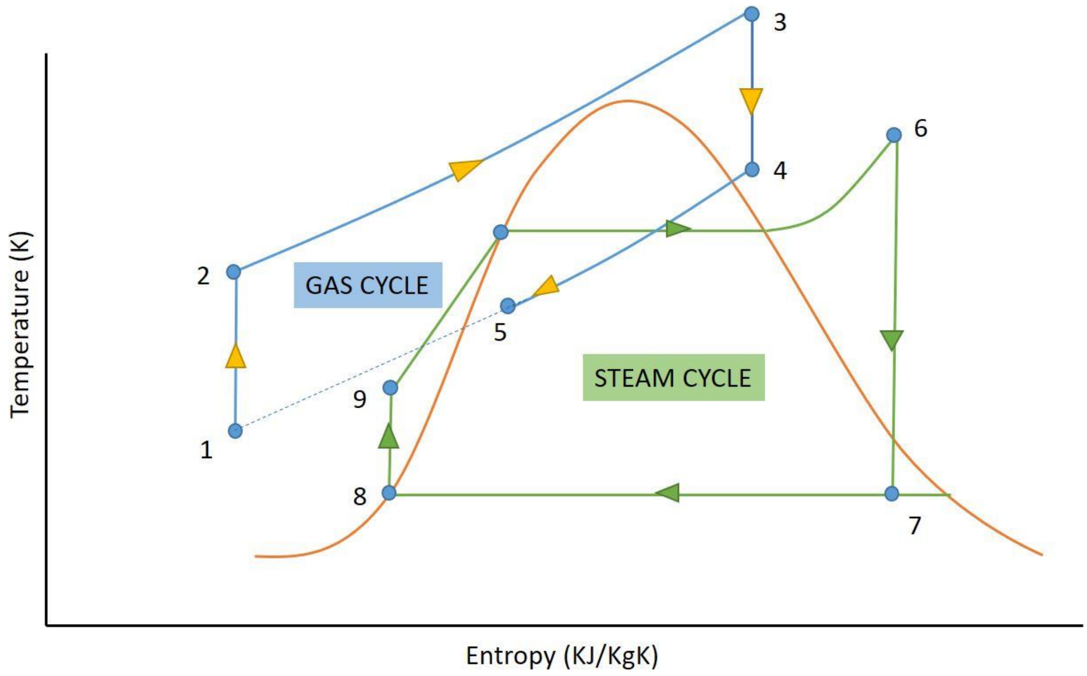

Figure: 3.2 T-S diagram of combined cycle

3.2.1 Combined cycle:

Combined cycle comprises of two cycles, first is Brayton Cycle and another is Rankine Cycle. Heat from the exhaust of the gas power cycle is utilized to produce steam in steam power cycle. Further this steam is utilize to produce power in a steam power plant.

A) Brayton Cycle: The cycle 1-2-3-4-1 represent gas power plant cycle. This simple Brayton Cycle consist of four processes which are explained as below:

- Process 1-2: In process 1-2, a compressor is used to compress the air to high pressure and high temperature.
- Process 2-3: In process 2-3, a boiler is used to supply heat to highly compressed air at constant pressure.

- Process 3-4: In process 3-4, air is expanded through a gas turbine to get a net-work output.
- Process 4-1: In process 4-1 heat rejection process at constant pressure occurs in a condenser as exhaust.

For producing steam in steam generator, the hot flue gas from gas turbine is utilize.

B). Rankine cycle: The cycle 8-9-6-7-8 is the Rankine steam cycle. It happens at a low temperature and furthermore it is known as the bottoming cycle. The cycle consists four processes which are explained as below:

- Process 8-9: Isentropic Compression (Pump); amid the isentropic pressure process, outer work is done on the working liquid by the pumping. Pumping happens from low to high weight.

- Process 9-6: Isobaric heat supply (Boiler or Steam Generator); In this working liquid is provided heat from higher temperature source for changing over it into superheated steam. Pressurized fluid entered in to kettle where it is gains heat at steady pressure to dry immersed vapour.

- Process 6-7: Isentropic extension (Steam turbine); an isentropic procedure, the entropy of working liquid stays consistent. The dry saturated vapour extend in the turbine, delivering power. The temperature abatements and pressure drops, and condensation may happen.

- Process 7-8: Isobaric heat removal (Condenser); an isobaric procedure, in this pressure of working liquid stays steady. In this procedure wet steam at that point goes into the condenser where it is consolidated at a consistent temperature and proselytes into saturated fluid.

3.3 COMBINED POWER PLANT CYCLE SYSTEM WITH ORGANIC RANKINE CYCLE AND ABSORPTION REFRIGERATION SYSTEM

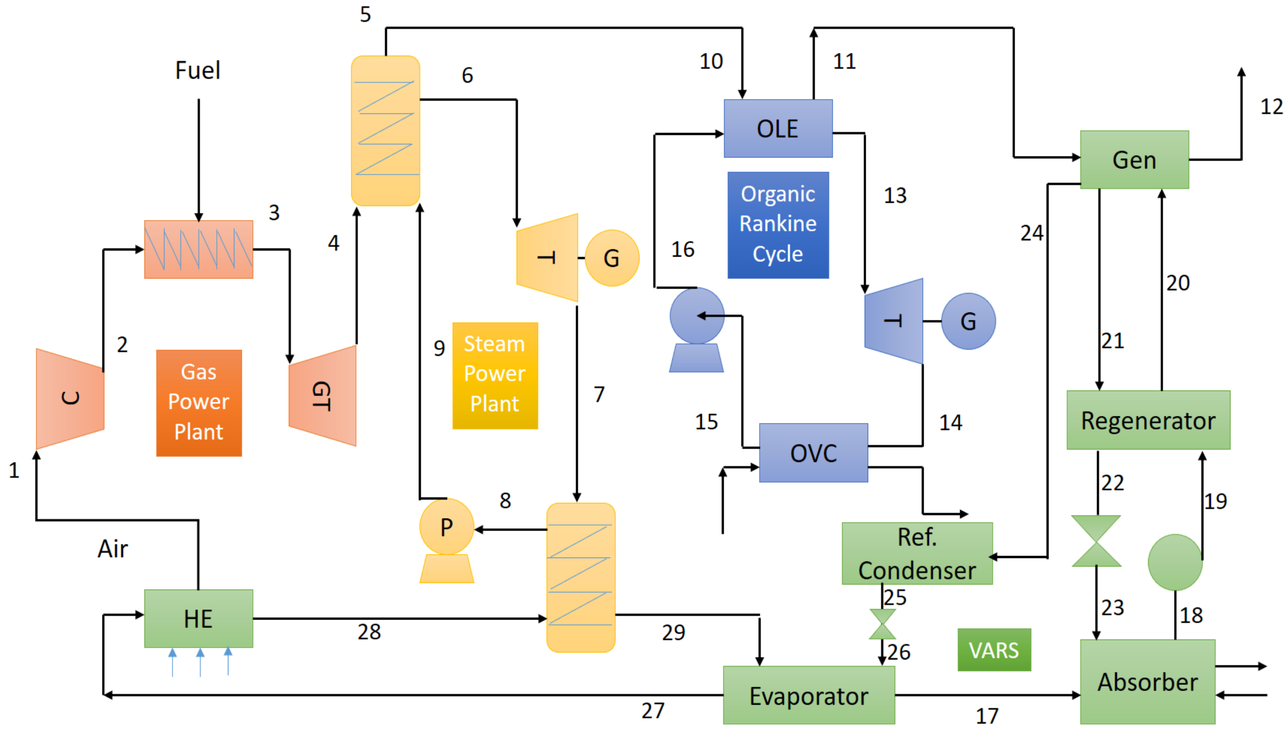

Fig 3.3 CCPP with organic Rankine cycle and Absorption refrigeration system

Above figure demonstrates combined cycle plant with natural Rankine cycle and vapour absorption cycle. In combined cycle, chilly air subsequent to experiencing heat exchanger goes into gas blower. It leaves the blower at stage 2 going before entering the combustion chamber (CC) where it mixes with the petroleum gas from the fuel supply structure for making hot vent gases, after that it clears out the burning chamber and went into the gas turbine .After that this hot fumes develop in the GT from state 3 to state 4, creating electricity by operating the turbine and for transform it in power. The exhaust vent gases at stage 4 go through the heat recovery steam generator (HRSG) where feed water streams inspired heat to stages 9 and 6. Flue gases clears out the HRSG at stages 4 to 5. Flue gas clearing out the HSRG at stage move through Organic Rankine cycle plant (ORC). Organic refrigerant gains heat from exhaust flue gas at stage 16 to 13 and becomes saturated vapour. The organic vapour is extended in the vapour turbine at stage 13 to create some extra electricity in generator. Then, organic liquid is consolidated in organic vapour condenser (OVC) to stage 15 and hence pumped by the fluid feed pump to stage 16, and bolstered into the OLE to proceed rehashing the cyclic methodology. The T-S diagram of combined cycle is shown in figure 3.2 while T-S diagram of the Organic Rankine Cycle is appeared in figure 3.4.

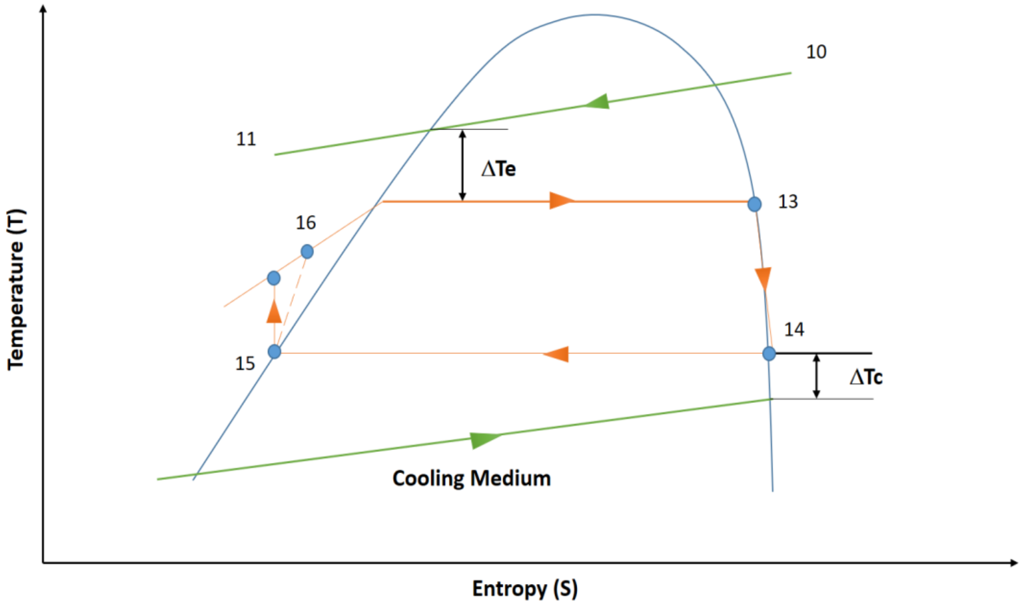

Fig 3.4 T-S diagram of Organic Rankine Cycle Power Plant

At point 11, the exhaust gases clearing out organic liquid evaporator units is utilized to control the LiBr-H2O cycle and after passing through generator it discharge at stage 12. The Absorption refrigeration cycle comprises of a generator, air-cooled condenser, regenerator, absorber, and evaporator. Weaken LiBr-H2O solution from absorber is pumped at stage 20 passing by regenerator and then to generator. In the generator, the debilitated arrangement is heated clearly by the fumes vent gases. A section of water is risen off from the LiBr-H2O course of action. The water vapour streams to the condenser while the concentrated LiBr-H2O arrangement at stage 21 returns through the regenerator to stage 22 and by methods for throttling gadget it goes to safeguard at stage 23. The rose off water vapour at 24 is united as it experiences the condenser. The resulting two-organize refrigerant is going through throttling gadget to low weight and low temperature to stage 25. After that it goes into the evaporator where it consumed heat from coursing water.

At stage 17, refrigerant vapour leaving from evaporator and return to absorber where, this is consumed by the strong solution coming from the generator at stage 23. The subsequent weakened solution at stage 21 is pumped to generator to finish the cycle. Cooled water from the evaporator is circled and cooling the surrounding air at stage 27 by using an air cooler. After the exit from air cooler at stage 28 this chilled water is also used in cooling the condenser water of steam power plant. After that it again passes through the evaporator of vapour absorption cycle for releasing heat and for completing the cycle.

3.4 EXERGY ANALYSIS:

Energy Equation solver is powerful computational mathematical tool which help in optimization of system by using various equation of system. Following equations of Combined Power plant cycle are considered to make an EES program and calculate the exergy losses in various components of a Combined Power Cycle.

Exergy destruction due to irreversibility in various components in the plant is given:-

a) Compressor

The power required for operating the compressor is given as, (3.1)

$$\dot{W}_{i,AC} = \dot{m}_2(h_2 - h_1) = \dot{m}_a C_{pa}(T_2 - T_1)$$

The actual compressor power is obtained by, (3.2)

$$\dot{W}_{a,AC} = \frac{\dot{W}_{i,AC}}{\eta_{s,AC}}$$

Where, isentropic efficiency of the compressor,

$$\eta_{s,AC} = 1 - \left(0.04 + \frac{(P_2/P_1) - 1}{150}\right) \tag{3.3}$$

Lost work of Exergy dissipation,

$$I_{compressor} = W_{a,AC} T_a (S_2 - S_1) \tag{3.4}$$

$$Where, (S_9 - S_8) = C_p ln\frac{T_9}{T_8} - R_a ln\frac{P_9}{P_8} \quad \text{(In Air)} \tag{3.5}$$

b) Combustor

Rate of Exergy dissipation or lost work,

$$I_{combustor} = \left[\left[W_g C_p ln\frac{T_6}{T_0} - W_g R_g ln\frac{P_6}{P_0}\right] - \left[W_g C_p ln\frac{T_9}{T_0} - W_a R_a ln\frac{P_9}{P_0}\right]\right] \tag{3.6}$$

c) Gas turbine

The ideal turbine power and actual turbine powers are given respectively,

$$\dot{W}_{s,GT} = \dot{m}_g(h_3 - h_4) = \dot{m}_g C_{pg}(T_3 - T_4) \tag{3.7}$$

and,

$$\dot{W}_{a,GT} = \dot{W}_{s,GT}\,\eta_{s,GT} \tag{3.8}$$

The turbine isentropic efficiency is given by,

$$\eta_{s,GT} = 1 - \left(0.03 + \frac{(P_4/P_3) - 1}{180}\right) \tag{3.9}$$

Rate of Exergy dissipation or lost work,

$$I_{GT} = W_{a,GT}\,T_0(S_7 - S_6) \tag{3.10}$$

$$Where, (S_7 - S_6) = C_p\frac{T_7}{T_6} - R_g ln\frac{P_7}{P_6} \qquad \text{(In Gas)} \tag{3.11}$$

The rate of heat transfer combined with the turbine exit exhaust gas is finding by,

$$\dot{Q}_{GT,exit} = \dot{m}_g C_{pg}(T_4 - T_1) = \left(1 - \eta_{I,GTC}\right)\dot{Q}_{cc} \tag{3.12}$$

The gas turbine net power output, $\dot{W}_{net,GTC}$, and cycle thermal efficiency $\eta_{I,GTC}$ are respectively, given as

$$\dot{W}_{net,GTC} = \dot{W}_{a,GT} - \dot{W}_{a,AC} \tag{3.13}$$

and,

$$\eta_{I,GTC} = \frac{\dot{W}_{net,GTC}}{\dot{Q}_{cc}} \tag{3.14}$$

d) Heat recovery steam generator [HRSG]

Heat transfer rates in HRSG,

$$\dot{Q}_{HRSG} = \dot{m}(h_6 - h_9) = \dot{m}_g C_{pg}(T_6 - T_9) \tag{3.15}$$

Rate of Exergy dissipation or lost work,

$$I_{HRSG} = T_0\left[W_{st}(S_a - S_e) + W_{gt}(S_2 - S_7)\right] \tag{3.16}$$

e) Steam turbine

Power output from steam turbines is given by,

$$\dot{W}_{st} = \eta_{s,ST}\, \dot{m}(h_6 - h_7) \tag{3.17}$$

Rate of Exergy dissipation or lost work,

$$I_{ST} = W_{st} T_0 (S_b - S_a) \tag{3.18}$$

f) Exhaust loss

Rate of Exergy dissipation or exergy loss due to flue gases,

$$I_{exh} = W_g C_p \left[(T_2 - T_0) - T_0 ln \frac{T_2}{T_0}\right] \tag{3.19}$$

$$\eta_{exergetic} = \frac{Total\, rate\, of\, exergy\, output}{Total\, rate\, of\, exergy\, input} \tag{3.20}$$

Steady-flow energy equation:

$$\dot{Q}_i + \dot{W}_i + \sum \dot{m}_i \left(h_i + \frac{v_i^2}{2} + gz_i\right) = \dot{Q}_e + \dot{W}_e + \sum \dot{m}_e \left(h_e + \frac{v_e^2}{2} + gz_e\right) \tag{3.21}$$

The energy or first law efficiency η_I of a system and/or system component characterized as the proportion of energy yield to the energy contribution to framework/segment.

$$\boldsymbol{\eta_I} = \frac{\boldsymbol{Desired\, output\, energy}}{\boldsymbol{Input\, energy\, supplied}} \tag{3.22}$$

Exergy adjust for a control locale experiencing a consistent stage process is communicated as-

$$\dot{X}_i + \dot{X}_j^Q = \dot{X}_e + \dot{W}_j + E\dot{D}_j \qquad (3.23)$$

$$\dot{X}_i = \textstyle\sum_{in} \dot{m}\, x \qquad (3.24)$$

$$\dot{X}_e = \textstyle\sum_{out} \dot{m}\, x \qquad (3.25)$$

$$\dot{X}_j^Q = \sum \left[\dot{Q}_j \frac{T-T_0}{T}\right] \qquad (3.26)$$

$$x = (h - T_0 s) - (h_0 - T_0 s_0) \qquad (3.27)$$

Where the 1st term of left and right hand side delineate physical exergy (disregarding potential, kinetic, and substance exergy part) of steam of issue entering and leaving the control area separately. The second term on left and right hand side is stream of heat exergy, which indicates exchange rate of exergy comparing to the heat exchange rate $\dot{Q}$ when control surface temperature is T at which heat transfer is occurs and exergy along with work transfer from the control region and to the control region. $E\dot{D}$ shows rate of exergy destruction.

3.5 THERMODYNAMIC ANALYSIS OF ORC UNIT

The evaporation temperature when the most extreme net power yield is come to known as the ideal evaporation temperature, T13, and it is managed by utilizing the improved equation.

$$T_{13} = \xi T^* = \xi\sqrt{T_{15}(T_{10} - \Delta T_e)} \qquad (3.28)$$

$$\xi = 0.999 + 0.00041(T_{10} - T_{16})/\left(h_{fg}/q^*\right) \qquad (3.29)$$

Where, ξ represents correction factor, latent heat of the organic liquid is represented by h_{fg} at the temperature T* and q* is heat of the working fluid (in kJ/kg) absorbed at the same condenser temperature. Hence,

$$q^* = C_{pw}(T^* - T_{15}) \qquad (3.30)$$

C_{pw} (KJ/kg. K) is the working fluid’s specific heat capacity.

Mass flow rate of the organic working liquid, $\dot{m}_w$ (kg/s), is given as,

$$\dot{m}_w = \dot{m}_g C_{pg} \frac{(T_{10} - T_{13} - \Delta T_e)}{h_{fg}} \tag{3.31}$$

The heat removal rate in organic liquid evaporator (OLE) is obtained by.

$$\dot{Q}_{OLE} = \dot{m}_g C_{pg}(T_{10} - T_{11}) = \dot{m}_w(h_{13} - h_{16}) \tag{3.32}$$

The exergy destruction rate in the OLE is given as,

$$I_{ole} = \dot{m}_w T_0 \left[(S_{13} - S_{16}) - \left(\frac{h_{13} - h_{16}}{T_h}\right)\right] \tag{3.33}$$

T_h represents the thermodynamic temperature of the heating system and given by,

$$T_h = (T_{10} - T_{11})/ln(T_{10}/T_{11}) \tag{3.34}$$

Organic vapour turbine power output is given by,

$$\dot{W}_{OVT} = \dot{m}_w \eta_E \eta_G (h_{13} - h_{14}) \tag{3.35}$$

Exergy destruction rate for organic vapour turbine is given by,

$$I_{ovt} = \dot{m}_w T_0 (S_{13}p - S_{14}) \tag{3.36}$$

Exergy destruction for organic fluid feed pump is obtained by,

$$I_{OLFP} = \dot{m}_w T_0 (S_{16} - S_{15}) \tag{3.37}$$

The rates of heat dismissal in the condenser is given as,

$$\dot{Q}_{OVC} = \dot{m}_w (h_{14} - h_{15}) \tag{3.38}$$

Exergy destruction in condenser is obtained by,

$$I_{ovc} = \dot{m}_w T_0 \left[(S_{14} - S_{15}) - \left(\frac{h_{14} - h_{15}}{T_L}\right)\right] \tag{3.39}$$

CHAPTER 4

RESULTS AND DISCUSSION

A scientific computational model is produced for playing out the vitality and exergy investigation of the framework utilizing EES programming.

Table.4.1 Input data to calculate exergy loss in various components

Inlet temperature in compressor	300 to 318 K
Pressure ratio	4 to 13
Inlet Pressure steam turbine	40 bar
Condenser pressure	0.45 to 9.45
Feed water temperature	170
Pressure drop in HRSG	0.04 bar
Steam flow rate	28.50 kg/s
Specific heat ratio of air	1.4
Specific heat ratio of gas	1.33
Pressure ratio of the compressor	8
Pressure drop in the combustion chamber	0.03

In the table 4.1 the inlet condition of air (specific heat ratio is 1.4) to the gas turbine power plant compressor is 1 bar and 300 K. Air is compressed to a compression ratio 8 in the compressor, and then it is extended in gas turbine. Inlet pressure to the steam turbine is kept approx. 40 bar. At that point air is extended through the steam turbine to a condenser pressure around 0.45-9.45 bar. There is a condition of steam at to the steam turbine weight drop of gas in HRSG is 0.04 bar.

RESULT:

- Exergy destruction for various components of combined cycle is shown in Table 4.2 and Fig.4.1.

Table 4.2 Exergy Destruction in various Components

Component	**Exergy Destruction(kW)**
Compressor	7312
Combustor	88685
Gas turbine	5681
HRSG	7845
Steam turbine	6372
Exhaust gases	17690

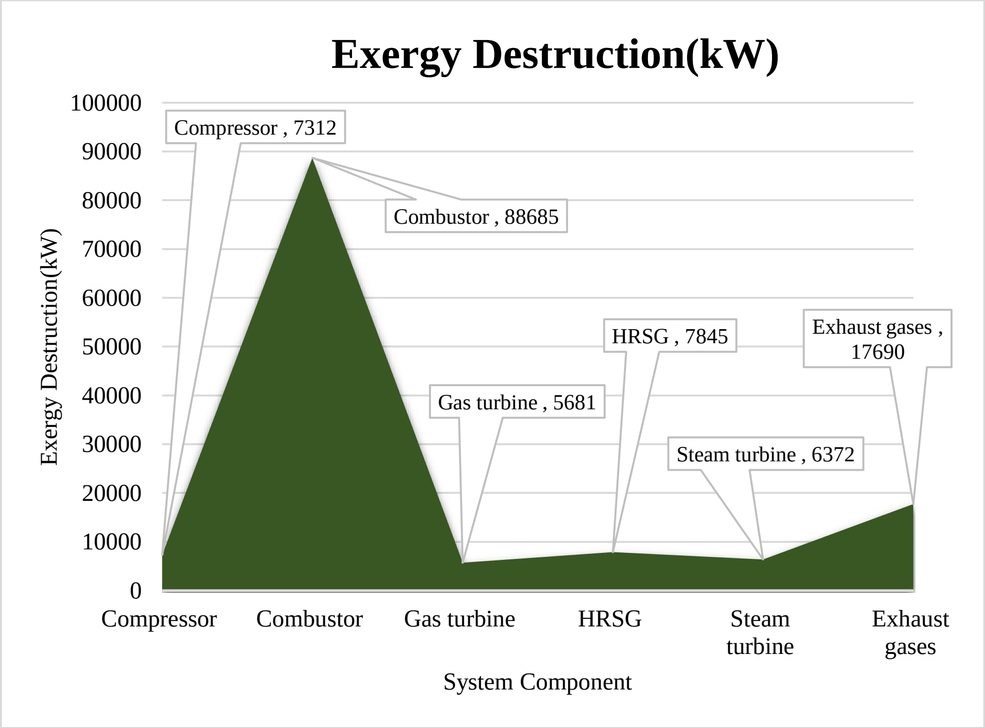

Fig.4.1 Exergy destruction in various component

It is quite clear from Fig. 4.1 that the maximum exergy destruction happens in the combustion chamber (88685 kW), followed by destruction due to exhaust gases (17690 kW), HRSG (7845 kW), compressor (7312 kW), steam turbine (6372 kW), and least destruction in gas turbine (5681 kW).

Variation of Exergy loss with respect to ambient temperature in various parts of the Cycle power plant is shown in Table.4.3. In the combustion chamber, the minimum value of exergy destruction is 86106 kW at the temperature of 318 K and the maximum value (88685 kW) at the temperature 300 K. It is seen that there decrease in exergy loss with increase in ambient temperature.

This is also seen that, overall exergy fall in plant with increase in ambient temperature.

Table.4.3 Losses in various components w.r.t ambient temperature

T1[k]	I_{comb}	I_{comp}	I_{exh}	I_{hrsg}	I_{st}	I_{gt}
300	88685	7391	17372	8015	6346	5750
302	88425	7472	16965	8077	6390	5786
304	88117	7543	16541	8144	6439	5825
306	87818	7618	16119	8201	6487	5861
308	87542	7691	15652	8259	6531	5898
310	87264	7769	15195	8317	6577	5937
312	87003	7842	14735	8375	6623	5973
314	86720	7911	14323	8436	6667	6010
316	86421	7982	13904	8490	6709	6046
318	86106	8056	13485	8547	6755	6083

It is clear from the table 4.4 that exergetic efficiency is minimum (30.67%) at temperature 318 K and maximum value (32.76 %) is obtained at a temperature of 300 K. It is clear from the table that gas plant efficiency is minimum (25.98%) at temperature 318 K and maximum value (27.05 %) is obtained at a temperature of 300 K.

Table: 4.4 Exegetic efficiency and Gas plant efficiency w.r.t. ambient temperature

T1[k]	η_{exer}	η_{GP}
300	0.3276	0.2705
302	0.3250	0.2694
304	0.3228	0.2682
306	0.3207	0.2671
308	0.3185	0.266
310	0.3162	0.2648
312	0.3139	0.2636
314	0.3116	0.2624
316	0.3093	0.2612
318	0.3067	0.2598

Variation of Exegetic efficiency, overall Efficiency and Steam plant efficiency w.r.t. boiler pressure are shown in table 4.5. Maximum value (32.71%) of exergetic efficiency was obtained at 40 bar and minimum value (32.34%) of at 58 bar. Maximum value (41.65%) of overall efficiency was obtained at 40 bar and minimum value (41.26%) of at 58 bar. Maximum value (40.35%) of steam plant efficiency was obtained at 58 bar and minimum value (38.84%) of at 40 bar.

Table: 4.5 Exegetic efficiency, overall Efficiency and Steam plant efficiency w.r.t. boiler pressure

P_{boiler}	η_{exer}	$\eta_{overall}$	η_{SP}
40	0.3271	0.4165	0.3884
42	0.3266	0.4161	0.3904
44	0.3262	0.4157	0.3923
46	0.3258	0.4153	0.3941
48	0.3254	0.4149	0.3959
50	0.3250	0.4145	0.3976
52	0.3247	0.4141	0.3991
54	0.3243	0.4136	0.4007
56	0.3239	0.4131	0.4021
58	0.3234	0.4126	0.4035

Variation of exergy loss in combustor, compressor, exhaust gases, HRSG and gas turbine with respect to pressure ratio is shown in table 4.6.

- Exergy loss is maximum for the combustor and it is increasing with the expansion of pressure ratio in combustor.
- Exergy loss for the compressor also additionally increments with increment in pressure ratio and its minimum value achieved is at a pressure ratio-4.
- Exergy loss for the exhaust also get increments with increment in pressure ratio and its minimum value achieved is at a pressure ratio-4.
- Exergy loss for the HRSG also decreases with increment in pressure ratio and its minimum value achieved is at a pressure ratio-13.
- Exergy loss for the gas turbine also get increments with increment in pressure ratio and its minimum value achieved is at a pressure ratio-4.
- Exergetic efficiency also get increments with increment in pressure ratio and its maximum achieved is at a pressure ratio-13.
- Exergetic efficiency of gas turbine also get increments with increment in pressure ratio and its highest value achieved is at a pressure ratio-13.

Table 4.6 Losses in various components w.r.t Pressure ratio

Rp	I_{comb}	I_{comp}	I_{exh}	I_{hrsg}	W_{gt}	η_{exer}	I_{gt}	η_{GP}
4	68142	2756	9754	9608	29542	0.3105	3085	0.2020
5	73445	3780	11178	9055	34256	0.3184	4130	0.2249
6	78752	4827	13119	8547	40118	0.3242	5103	0.2446
7	83876	5987	15045	8072	45266	0.3261	5921	0.2596
8	88685	7312	16990	7745	51527	0.3268	6778	0.2713
9	94063	8740	19117	7446	58019	0.3251	7564	0.2790
10	99875	10367	21912	7212	64052	0.3224	8277	0.2866
11	105402	12053	24980	6985	70087	0.3180	9102	0.2912
12	112290	13789	28731	6777	76020	0.3112	9994	0.2950
13	119682	15892	32352	6590	82125	0.3057	10729	0.2964

Variation of exergy loss in combustor, compressor, exhaust gases, HRSG steam turbine and gas turbine with respect to boiler pressure is shown in table 4.7. It is observed that with increase in boiler pressure Exergy loss is maximum for the combustor and it is increasing with the increase in boiler pressure in the combustor.

Table 4.7 Losses in various components w.r.t. boiler Pressure

P_{boiler}	I_{comb}	I_{comp}	I_{exh}	I_{gt}	I_{hrsg}	I_{st}
40	88685	7391	17372	5750	8015	6346
42	89267	7439	17718	5788	7902	6370
44	89836	7486	18127	5824	7796	6393
46	90392	7532	18563	5860	7696	6414
48	90937	7577	19004	5895	7601	6434
50	91471	7621	19432	5929	7512	6452
52	91994	7664	19859	5963	7427	6470
54	92508	7706	20282	5997	7347	6486
56	93012	7748	20701	6018	7271	6501
58	93507	7789	21115	6025	7198	6515

Table 4.8 Variation in component w.r.t condenser pressure

$P_{condensor}$	η_{exer}	η_{SP}	$\eta_{overall}$
0.4	0.3482	0.3056	0.3921
1.4	0.3539	0.2549	0.3693
2.4	0.3564	0.2160	0.3584
3.4	0.3581	0.1963	0.3510
4.4	0.3595	0.1841	0.3453
5.4	0.3605	0.1686	0.3406
6.4	0.3614	0.1578	0.3365
7.4	0.3621	0.1482	0.3329
8.4	0.3627	0.1395	0.3296
9.4	0.3632	0.1316	0.3267

Variation of Exegetic efficiency, steam plant and overall efficiency with respect to condenser pressure is shown in table 4.8. It is observed that with increase in condenser pressure the Exegetic efficiency increase and maximum value is 36.32% and the steam plant efficiency is decreased with increasing the condenser pressure, overall efficiency also decrease.

Variation of Exegetic efficiency, exergy deficiency in CC with respect to pressure drop is shown in table 4.9.

Table 4.9 Variation in component w.r.t Pressure drop

P_{drop}	I_{comb}	I_{gt}	W_{gt}	η_{exer}	η_{GP}	**P drop in CC**
2	89192	5827	53583	0.3397	0.2680	0.16
3	88685	5750	52590	0.3381	0.2653	0.24
4	88178	5684	51602	0.3365	0.2625	0.32
5	87672	5607	50617	0.3349	0.2597	0.4
6	87165	5531	49637	0.3332	0.2569	0.48
7	86658	5454	48660	0.3315	0.2541	0.56
8	86152	5379	47687	0.3298	0.2512	0.64
9	85645	5301	46719	0.3281	0.2482	0.72
10	85137	5224	45755	0.3264	0.2453	0.8
11	84631	5147	45059	0.3246	0.2423	0.88

Table 4.10 Variation of efficiency w.r.t compressor inlet temperature

Compressor inlet air temperature	**Integrated plant Exergy efficiency**	**Integrated plant Thermal efficiency**
15	49.8	51.9
17	48.1	50.3
19	46.4	48.6
21	44.7	46.9
23	43.1	45.2
25	41.6	43.5
27	40.1	41.8
29	38.5	40.1
31	37.1	38.3
33	35.7	36.8

Table 4.11 Variation of efficiency w.r.t pressure ratio

Pressure Ratio	Integrated plant Exergy efficiency	Integrated plant Thermal efficiency
4	35.7	37.2
5	41.5	43.1
6	45.7	47.3
7	48.6	50.3
8	49.7	51.4
9	49.6	51.4
10	48.8	50.7
11	47.1	49.2
12	44.6	46.9
13	41.6	44.1

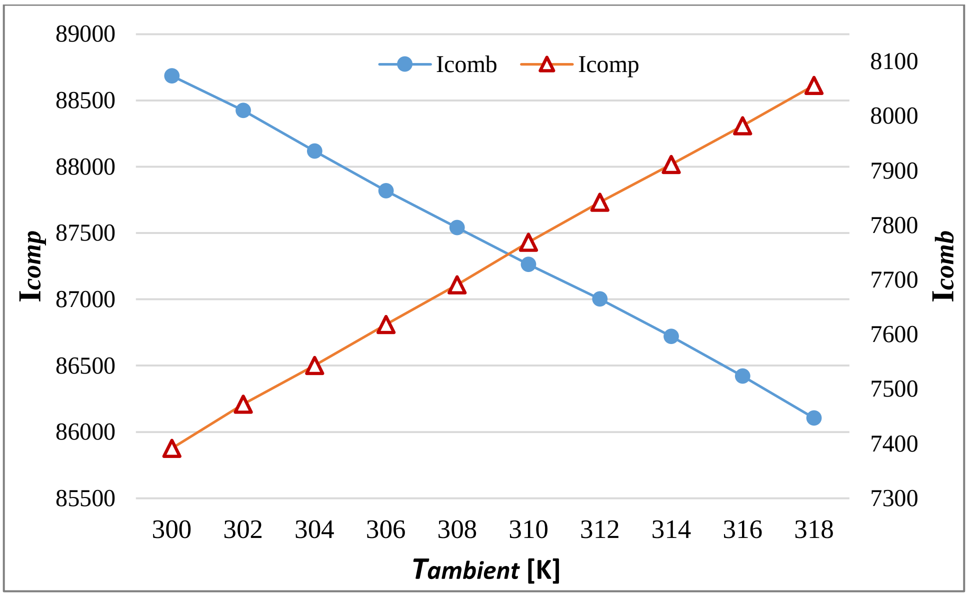

Figure: 4.2 Exergy loss (combustor and compressor) v/s ambient temperatures

In the Figure 4.2 shows, the exergy loss in combustor is decreasing with the variation of ambient temperature in the range 300 to 318 K and in compressor exergy loss increasing.

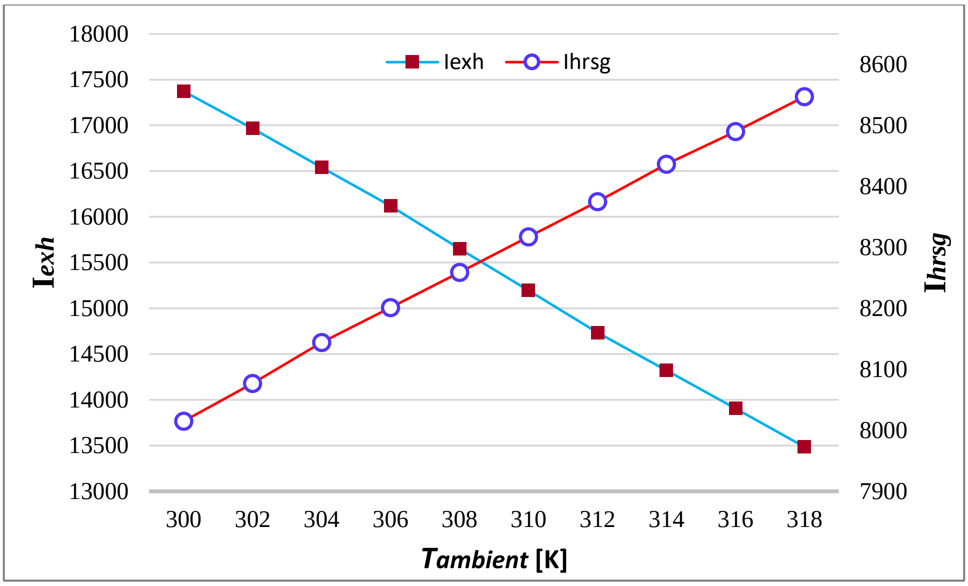

Figure: 4.3 Exergy loss (exhaust and HRSG) v/s ambient temperatures

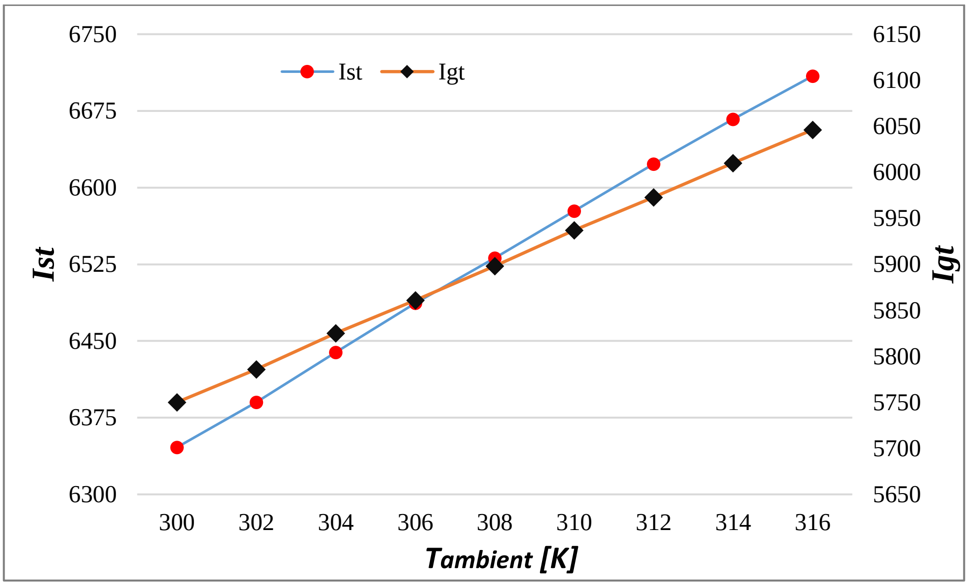

Fig: 4.4 Exergy loss (steam turbine and gas turbine) v/s ambient temperature

In the Figure 4.3 presents the amount by which Exergy dissipation takes place in heat recovery steam generator is increasing with increasing the ambient temperature and exhaust loss due to flue gases is decreasing.

In Figure 4.4 presents amount by which Exergy dissipation takes place in steam turbine or lost work is increasing with increasing the ambient temperature and lost work in gas turbine is slightly less with increasing the ambient temperature.

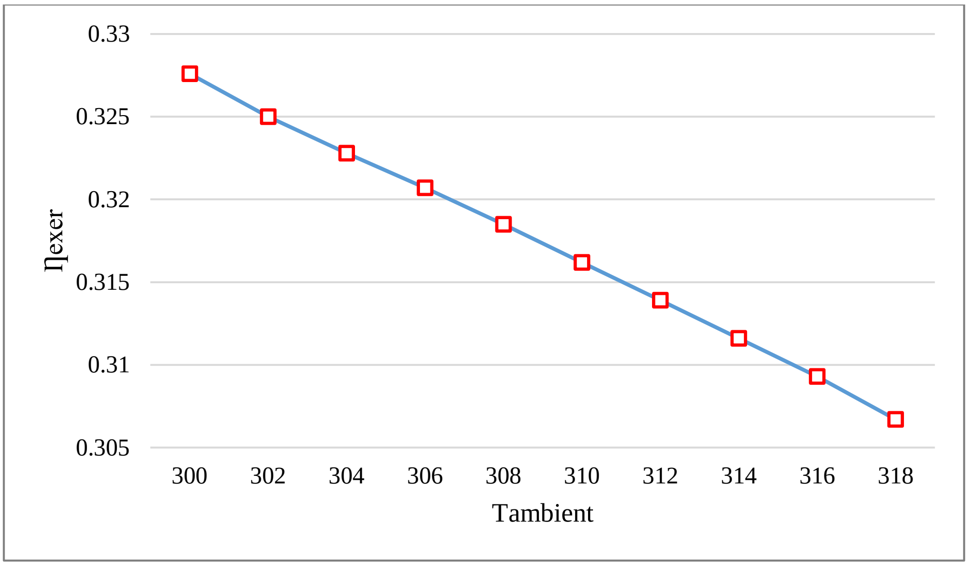

Fig: 4.5 Exergetic efficiency v/s ambient temperature

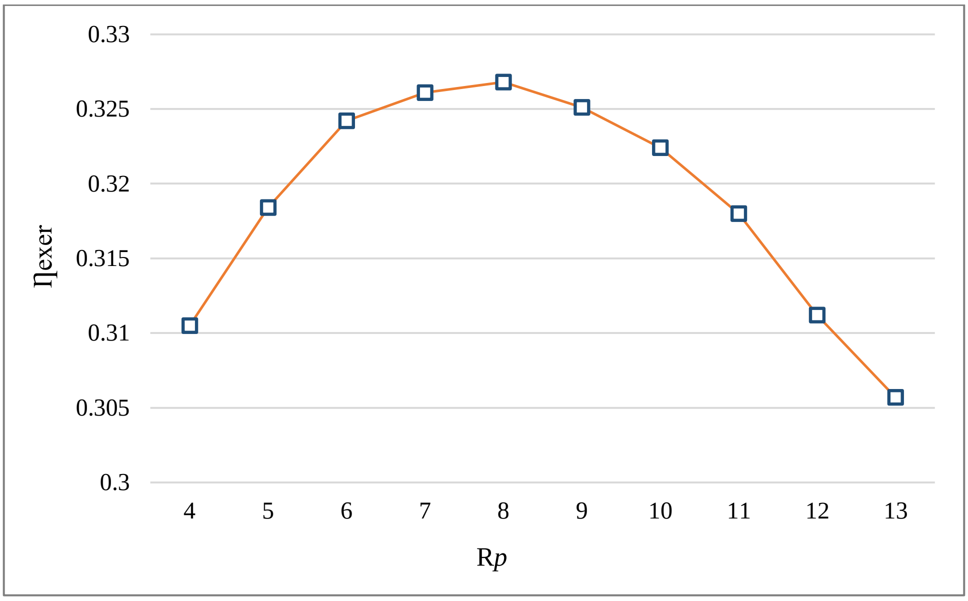

Fig: 4.6 Exergetic efficiency v/s pressure ratio

In Fig. 4.5 Exergetic efficiency is decreasing with increasing ambient temperature, because the condenser pressure would be higher at higher ambient temperature. Hence the condenser saturation temperature would also be higher. So at higher ambient temperature efficiency will be low.

In the Fig. 4.6 Exergetic efficiency firstly increase with increasing pressure ratio and have maximum value at pressure ratio (8.0) approximate. And further increasing the pressure ratio Exergetic efficiency is decreasing

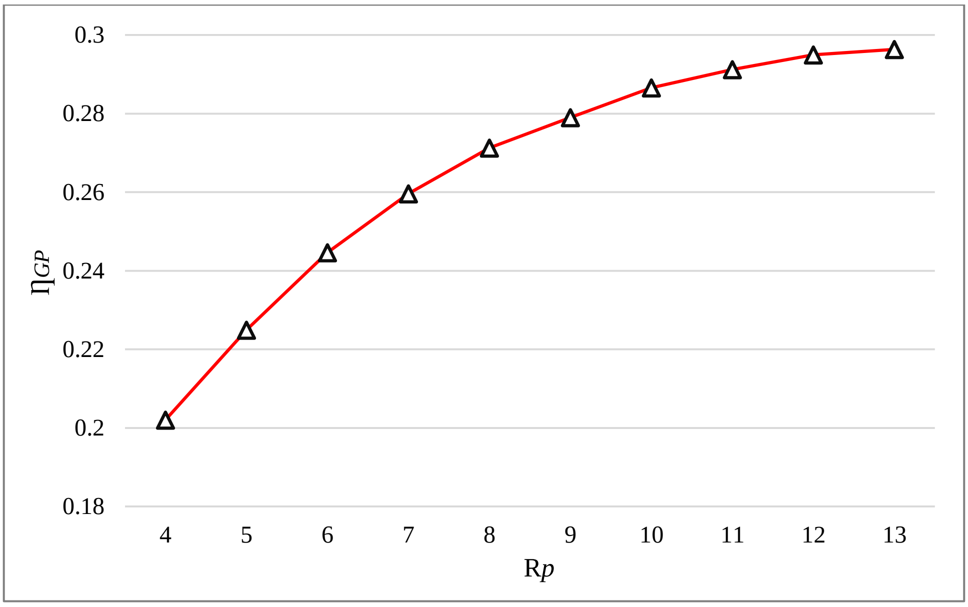

Fig: 4.7 Efficiency (gas plant) v/s Pressure ratio

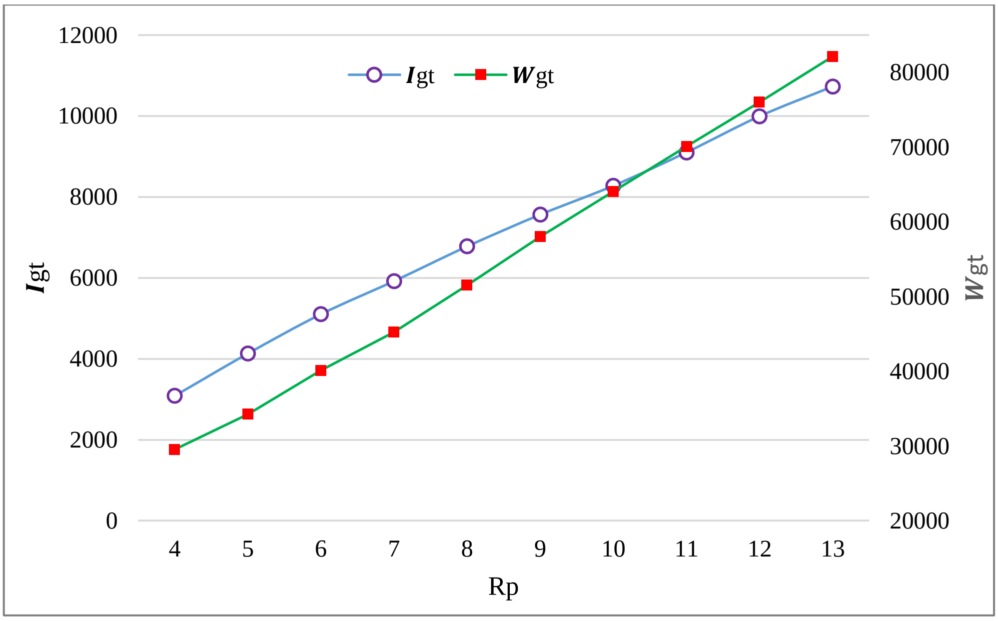

Fig: 4.8 Exergy losses in Gas turbine and power output (GT) v/s pressure

In Fig 4.7 Efficiency of gas plant is increases with increase in pressure ratio, but after pressure ratio = 12 rate of increase of efficiency w.r.t. pressure ratio is very less i.e. it is nearly constant (30% maximum).

In Figure 4.8 Exergy loss or irreversibility into gas turbine gain increments with increment in pressure ratio and in gas turbine output also increase with increasing the pressure ratio.

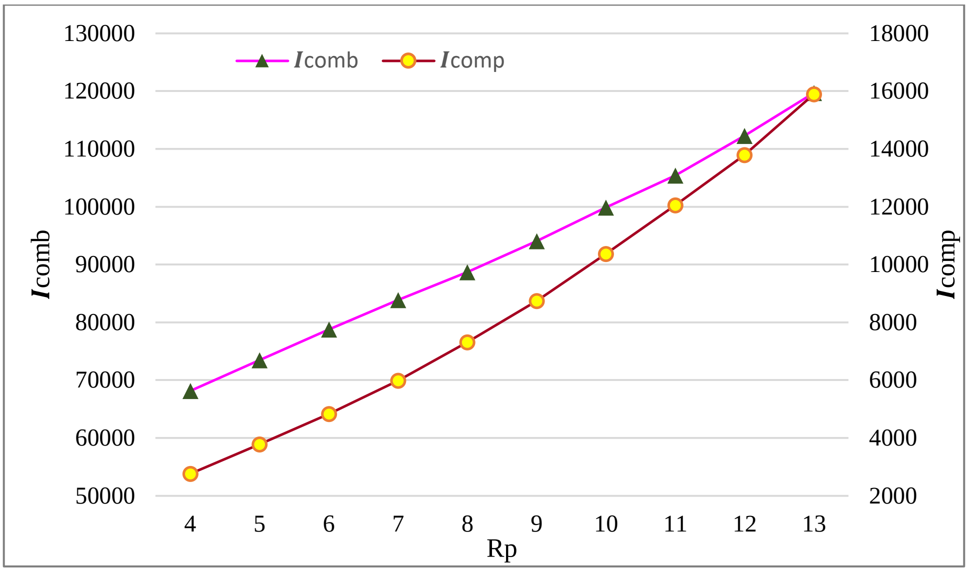

Fig: 4.9 Exergetic loss in combustor and compressor v/s pressure ratio

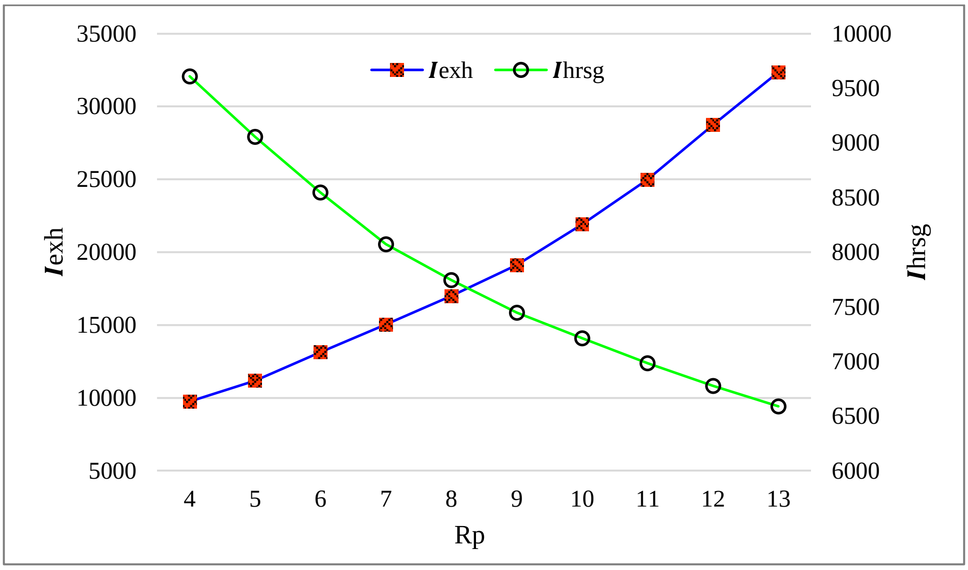

Figure: 4.10 Exergy loss (exhaust gases) v/s pressure ratio

In Figure 4.9 Exergy losses in combustor and compressor is increasing with increasing pressure ratio. Again, the behaviour of the intermediate section is following the same trend. This is because of most noteworthy temp of the working liquid, chemical reactions and a little drop in pressure.

In the Figure 4.10 Exergy misfortune in flue gases is get increments with expanding weight proportion, while in HRSG there is a diminishing in exergy loss is seen with increment in pressure ratio.

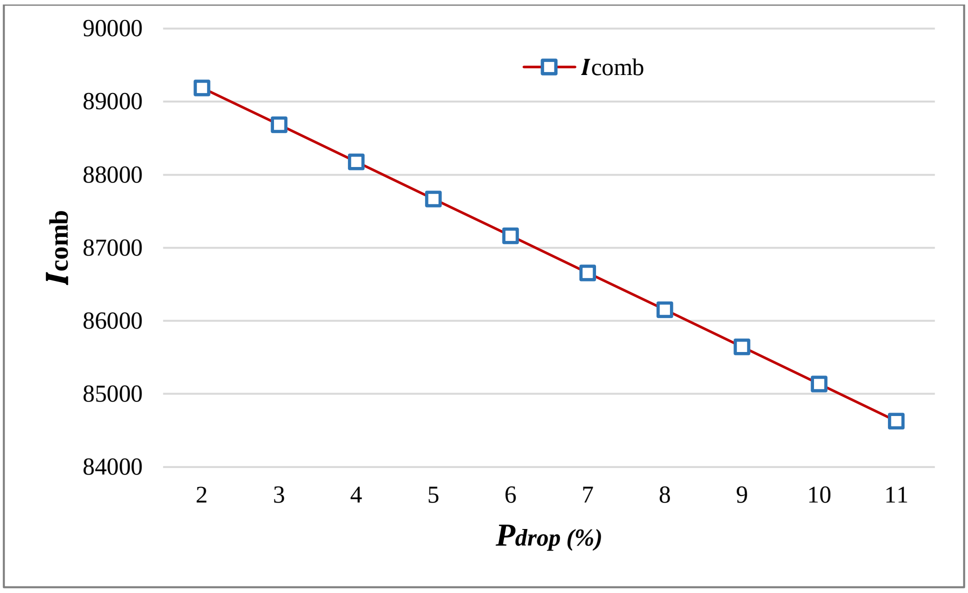

Figure: 4.11 Exergy loss (combustor) v/s pressure drop

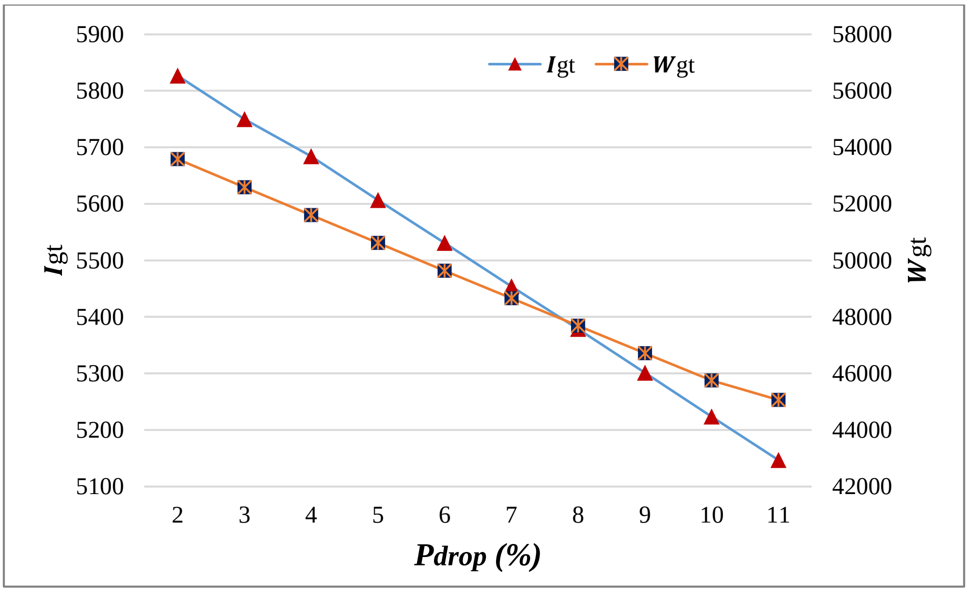

Figure: 4.12 Exergy loss (GT) v/s pressure drop

In the Figure 4.11. Exergy loss in combustor is decreasing linearly with increase in pressure drop.

In the Figure 4.12 Exergy damage in GT and output of gas turbine both follow linear relation with variation in pressure drop. Exergy damage in GT decreases with increase in pressure drop and output of the gas turbine also diminishes with increment in pressure drop.

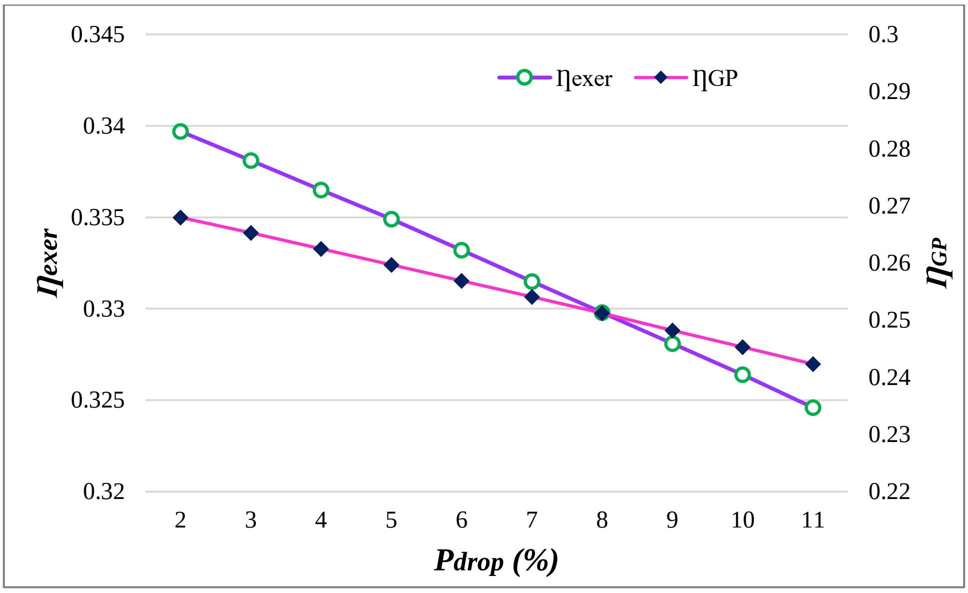

Figure: 4.13 Exergetic efficiency and gas plant efficiency v/s pressure drop

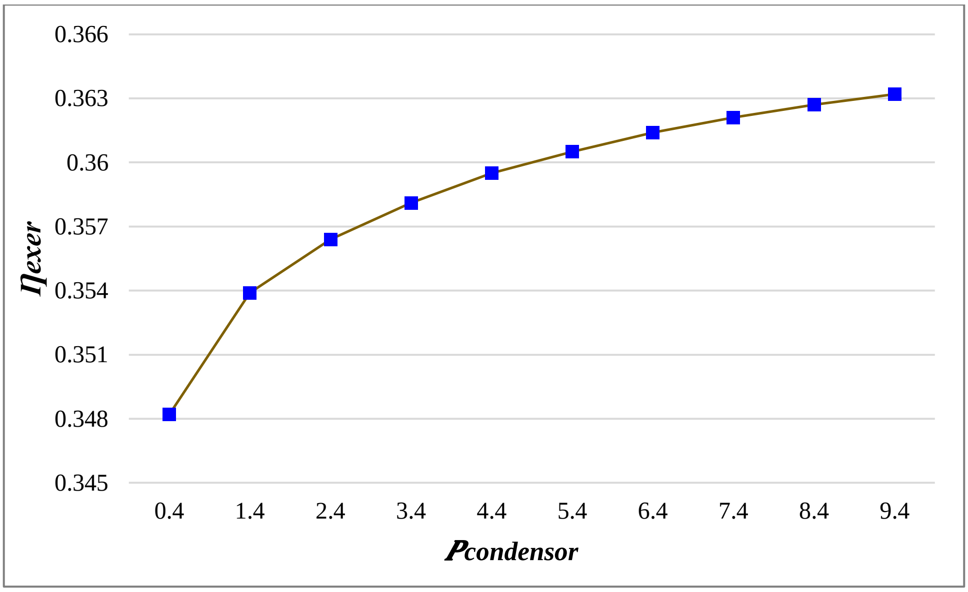

Figure: 4.14 Exergetic efficiency v/s Condenser pressure

In the Figure 4.13 Exergetic efficiency decreases with increase in pressure drop and gas power plant efficiency is decreasing with increase in pressure drop.

In Fig. 4.14 indicates the variation of exergetic efficiency plant w.r.t. condenser pressure. Exergetic efficiency is increases with increases in condenser pressure. At lower pressure it increases at faster rate as compared to increasing rate at higher pressure.

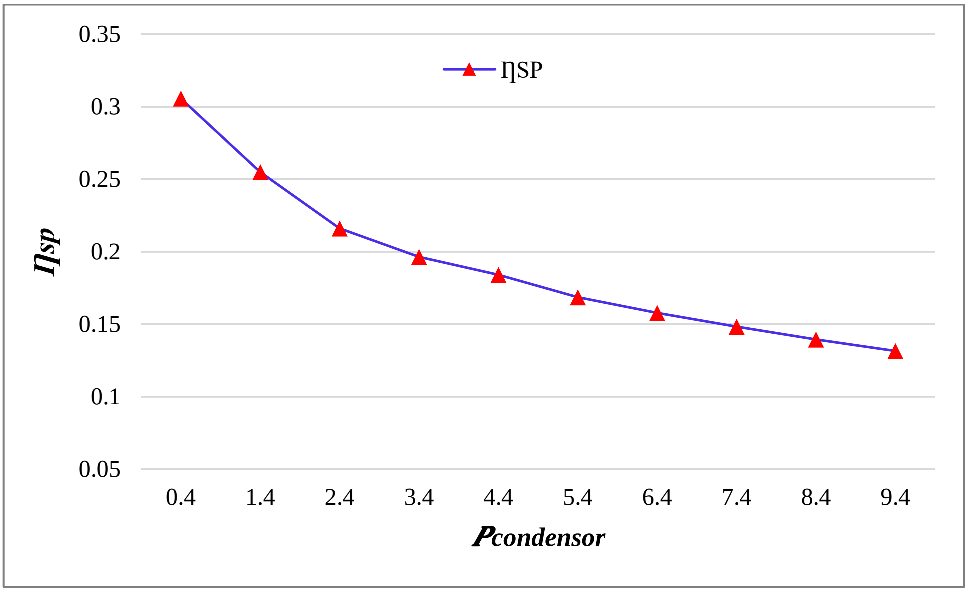

Figure: 4.15 Exergetic efficiency (SP) v/s Condenser pressure

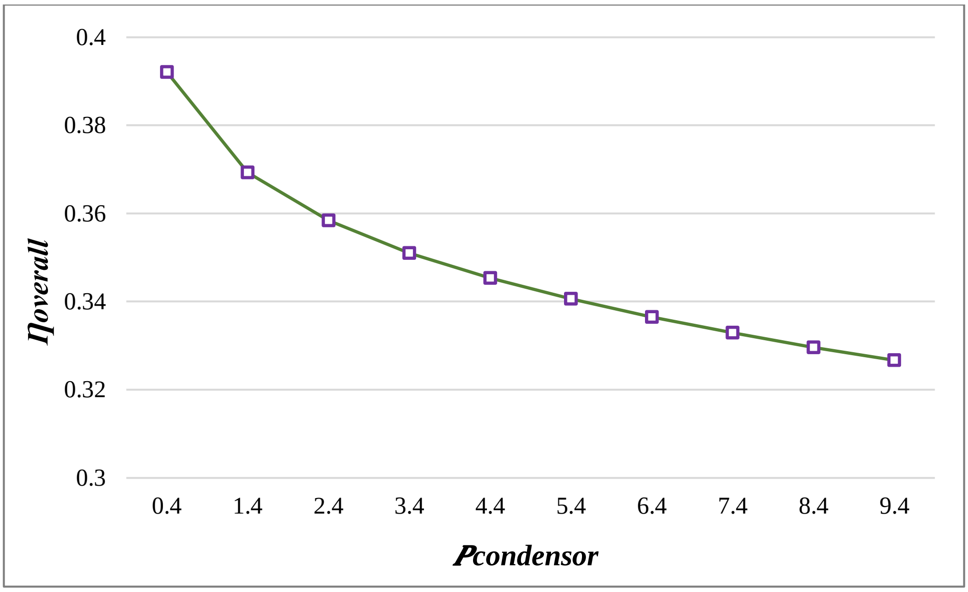

Figure: 4.16 Overall efficiency (plant) v/s Condenser pressure

In Figure 4.15 indicates the variation of efficiency of steam power plant w.r.t. condenser pressure. Exergetic Efficiency of steam plant is decreasing with increase in condenser pressure.

In Figure 4.16 indicates the variation of overall efficiency of plant w.r.t. condenser pressure. Overall efficiency of the plant decreasing with Increase in condenser pressure.

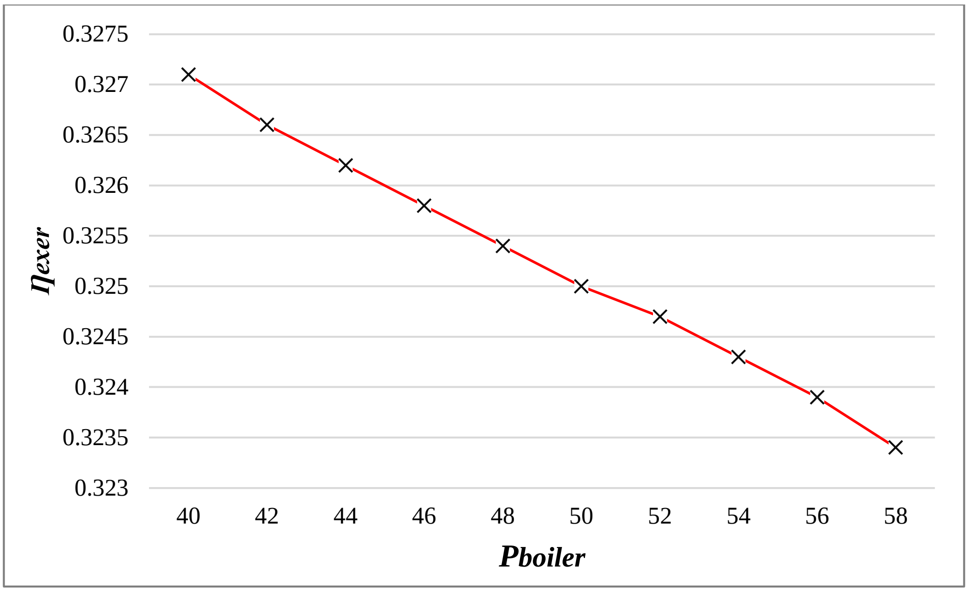

Figure: 4.17 Exergetic efficiency v/s Boiler pressure

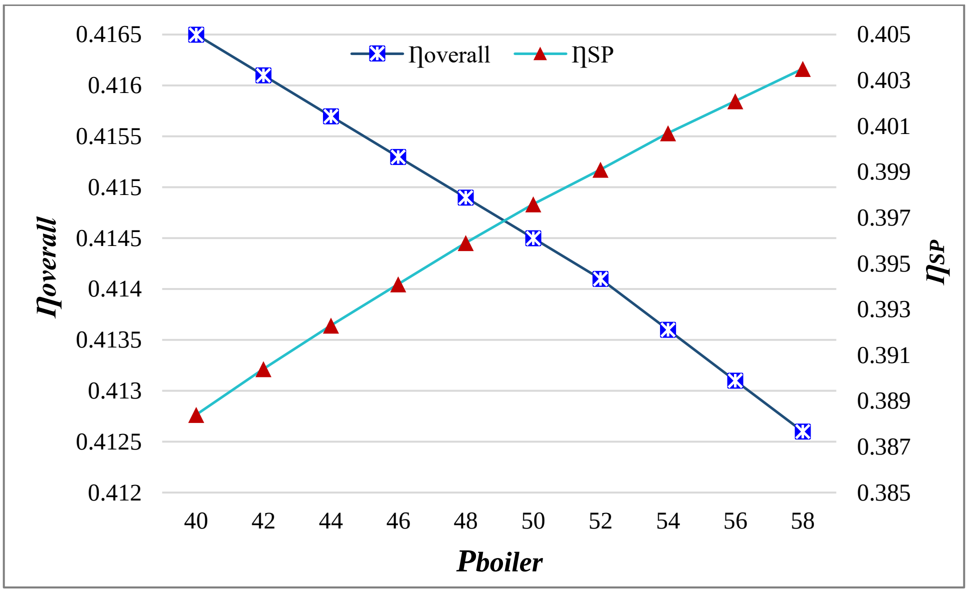

Figure: 4.18 Overall efficiency v/s Boiler pressure

In Figure 4.17 Exegetic efficiency decreases with increase in boiler pressure and maximum Exergetic Efficiency achieved at 32.71 at boiler pressure 40bar.

In Figure 4.18 Overall efficiency decreases with increase in boiler pressure and at 40 bar maximum efficiency 41.65.

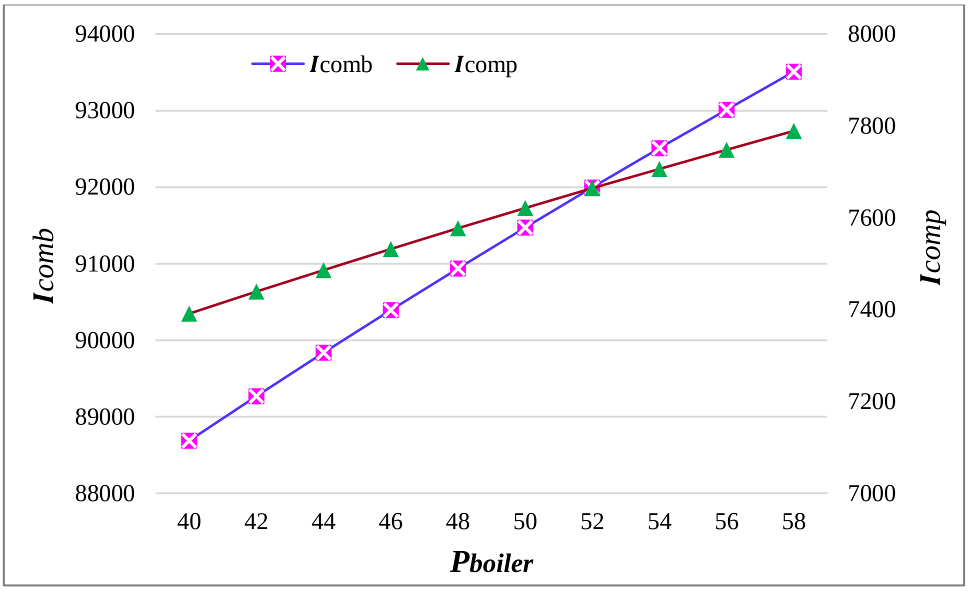

Figure: 4.19 Exergy dissipation in combustor and compressor v/s condenser pressure

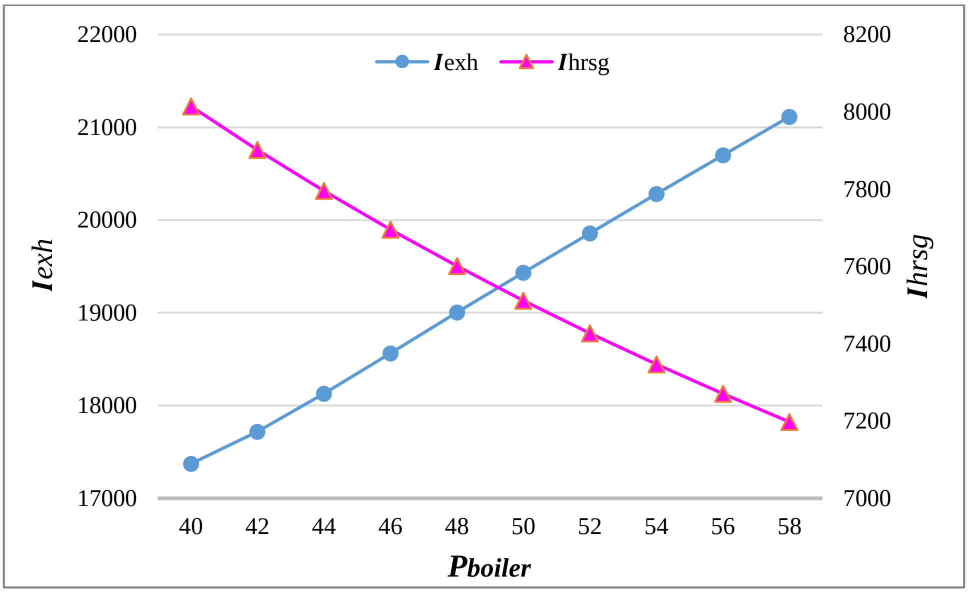

Figure: 4.20 Exergy dissipation in combustor and compressor v/s Boiler pressure

In Figure 4.19 exergy loss in combustor and compressor is increasing with increasing the boiler pressure.

In Figure 4.20 the Exergy dissipation is increasing with increasing the boiler pressure in the exhaust gases.

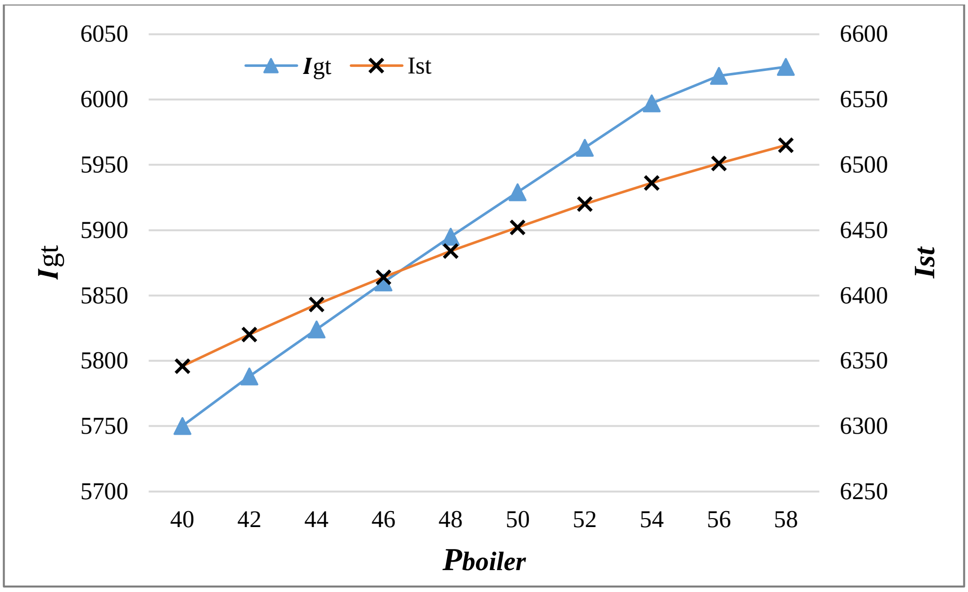

Figure: 4.21 Exergy dissipation in GT and ST v/s Boiler pressure

In Figure 4.21 Exergy dissipation in steam turbine and gas turbine dissipation is increasing with increasing the boiler pressure.

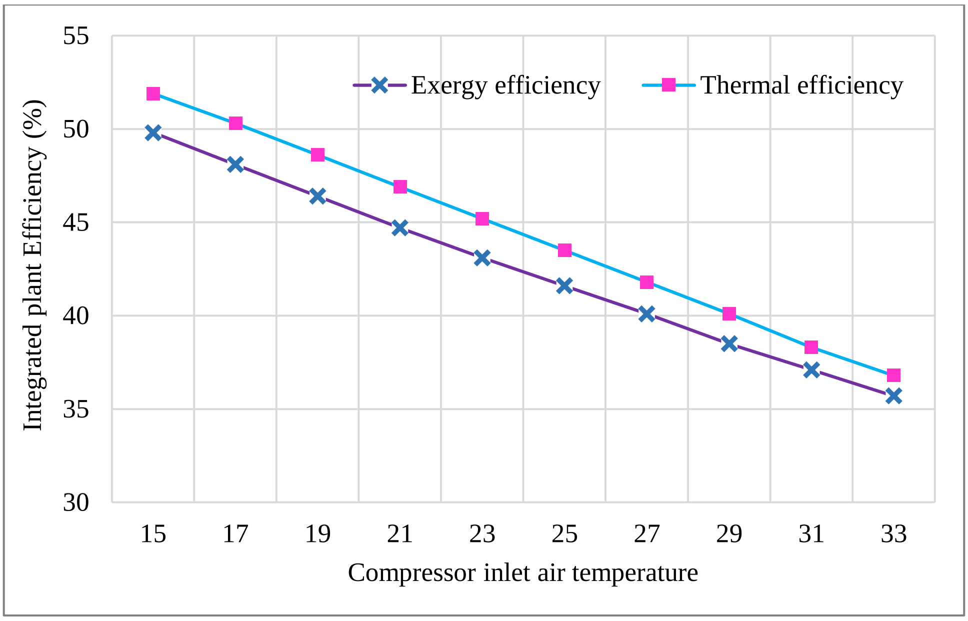

Figure: 4.22 Impacts of inlet air temperature of compressor on thermal and exergy efficiencies of the integrated power plant.

Figure 4.22 represents, variation of thermal and exergy efficiencies regarding compressor inlet temperature. As compressor inlet temperature increases the efficiency of integrated thermal power plant and exergy efficiency decreases. Hence cooling of compressor inlet air by applying a heat exchanger becomes beneficial since it improves our plant efficiency.

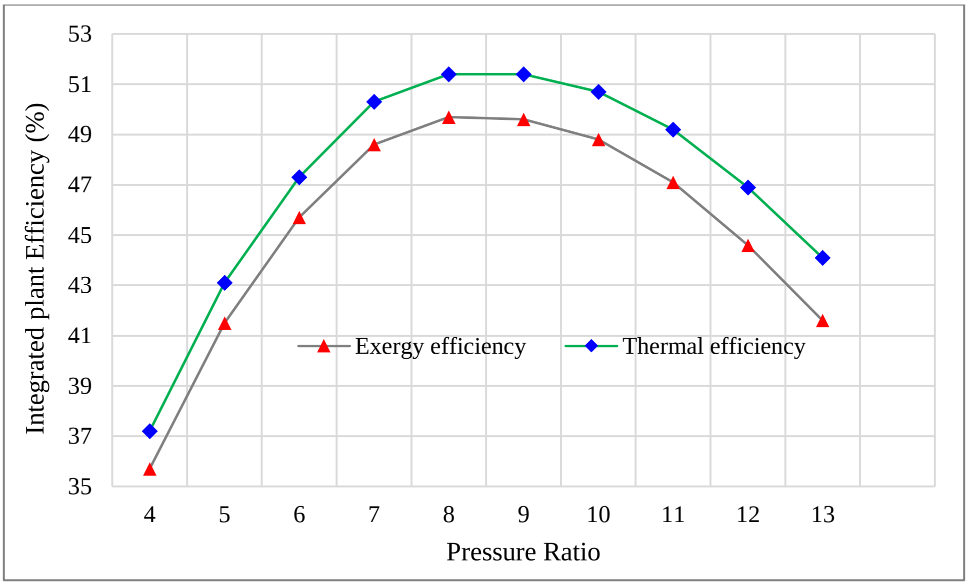

Figure: 4.23 Integrated plant thermal and exergy efficiencies w.r.to pressure ratio

Above graph represents the change in thermal and exergy efficiencies w.r.t compressor pressure ratio. As pressure ratio get increment, the integrated plant thermal efficiency start increasing. After reaching certain pressure the efficiency becomes maximum and then start decreasing. Same pattern also followed by the exergy efficiency.

CHAPTER 5

CONCLUSION & FURTHER SCOPE

5.1 CONCLUSION

Amid this broad vitality and exergy investigation of Integrated combined cycle following conclusions are abridged beneath:

- This integrated combined cycle control plant offers more noteworthy proficiency and greater condition cordial when contrasted with simple combined cycle because in this integrated cycle, low grade energy i.e. exhaust gas is used for extra power generation in Organic Rankine cycle and for obtaining chilled water from vapour absorption system.
- Exergy examination is introduced in this theory to have the capacity to help comprehend the execution of Integrated combined cycle.
- It gives us an efficient procedure to creation the most extreme power .By the exergy examination, it can inferred that principle exergy loss happens in the boiler in steam power plant and in ignition chamber in the gas power plant.
- Result showed that as compressor inlet temperature diminish, thermal efficiency along with exergy efficiency increments occurs and overall exergy destruction along with specific fuel consumption of plant diminish.
- Low cycle efficiency, because of the very high exhaust loss, high compressor work and other parameters.
- The rule of expanding productivity in the joined cycle plant is identified with the expansion of the mean temperature of the heat supply and the decline in mean temperature of heat removal.
- There is an increment in the exit temperature at compressor outlet for a greater pressure ratio. Accordingly, for a predetermined turbine entrance temperature, the exergy devastation inside the combustor diminishes.
- The prime energy destruction takes place in heat recovery framework that results to incapable heat exchange between cool flow of water or air, and hot flow of flue gas.
- It has been seen that, combustor is main place where maximum exergy loss takes place. It reveal that combustor isn't totally adiabatic and complete burning may not be happens. It is because of the irreversibility inside the ignition

procedure. This investigation demonstrates that the combustor needs important change, for example, obstinate (protection) alteration for diminishing exergy devastations and consequently plant execution can be expanded.

5.2 VALIDATION

I found that the most extreme exergy destruction happened in the burning chamber and least exergy destruction happened in gas turbine, which are in accordance with the survey from the literature.

5.3 FURTHER SCOPE

This work would uncover main source of misfortunes and exergy obliteration in the combined power plant. It would give numerous ways and diverse technique to enhance the execution of framework and furthermore to reduce environment loss. At long last, to decide the variety of framework execution with various working parameters, parametric investigation will perform.

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