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EVALUATION OF PRICE FOR EXERGY DESTRUCTION IN COMBINE HEAT AND POWER SYSTEM

Amit Pratap[1], Nikhil Dev[2], Jat Hareshwar[3]
[1]Sobhasaria group of institutions, Sikar, India.
[2]YMCA University of Science and Technology, Faridabad, Haryana, India.

Abstract: Exergy-based cost analysis aims at determining the costs of products and irreversibility (exergy destroyed) generated in energy conversion processes. This combination of exergy analysis with economic concepts is called thermo economic analysis. In this present work analysis the cost of exegy destruction in sub-system of gas turbine power plant and find the evolution of price for exergy destruction in each component of gas power plant operate on per unit fuel consumption and also study the two factors which effect cost of exergy destruction in gas turbine power plant component are turbine inlet temperature (TIT) and cycle pressure ratio (CR).
Keyword: Exergy destruction, Turbine inlet temperature (TIT) and Cycle pressure ratio (CR), Exergy destruction cost.

I. INTRODUCTION

Cogeneration is most efficient when heat can be used on-site or very close to it. Overall efficiency is reduced when the heat must be transported over larger distance. This required heavily insulated pipes. Which are expensive and inefficient, Cogeneration is one of the most costs efficient methods of reduce carbon emissions from heating system in cold climates and is recognized to be the most energy efficient method of transforming energy from fossil fuels or biomass into electricity power. Cogeneration plants are commonly found in district heating system of cities, central heating systems from building, hospital and are commonly used in industry in thermal production process, cooling steam production or carbon dioxide fertilization. Parametric analysis of a 30 MW gas turbine cycle in the last attempt to work out from which the waste heat is transferred to the air compressor outlet, the remaining heat is transferred to water pressure in the steam generator, Heat rejected to atmosphere through stack is minimized. A cogeneration system is a sequential and simultaneous generation of multiple form of useful energy (mechanical and thermal) in a single and integrated system. Thermal power plants and heat engine in general, do not convert all of their energy into electricity. A Cogeneration plant can either meet the need for heat (heat driven operation) or run as a power plant with some use of its waste heat. By using cogeneration system European countries are generated 11% of its electricity power. There are three countries in Europe (Denmark, Finland and Netherland) who are with intensive response in cogeneration power and contributing to economy of Europe. In August 2007, Integrated Energy and Climate Protection Program (IECPP) started by the German government in Merseburg contain the target of doubling the share of CHP generation in Germany by 2020. After this share of CHP systems in power generation will rise to 25%. Germany is presented a report that 50% of the country's total electricity demand could be provided through cogeneration Now Germany has set the target to double its electricity cogeneration from 12.5% of the country's electricity to 25% of the country's electricity by 2020 and has passed supporting legislation accordingly. European Union starting a program on cogeneration expansion with a view that power generation will take place with higher efficiency & lower pollution emission by 2030. UK has made a goal to achieve a 60% reduction in carbon dioxide emissions by 2050 in comparison to present emission. UK measures to encourage CHP growth are financial incentives, greater regulatory framework and government leadership and to achieve the objective eight clean energy applications have been established across the nation, whose mission is to develop the required technology about all application knowledge and educational infrastructure necessary to lead "clean energy" and heat and power India also most developing country in cogeneration power, many cogeneration gas power plant generating electrical energy use as auxiliary power for conventional plant running in India. Our renewable energy resources and combined heat and power generation (CHP) are to play a more important role in the future.

II. SYSTEM DESCRIPTIONS

For Thermal system design and analysis, thermodynamics, heat transmission, fluid mechanics, manufacturing and design principles are engrossed. A 30 MW cogeneration cycle (Figure 3.1) have been studied in the present work. Ambient air enters the compressor and after compression its temperature and pressure is increased. Compressed air is passed through a regenerator where high temperature combustion gases coming out of gas turbine transfer their heat to the compressed air. After gaining heat, compressed air comes to combustion chamber and fuel is added. After burning with air, chemical energy of fuel is converted into thermal energy. Combustion products temperature depends upon turbine inlet temperature (TIT) which is fixed by thermal stress limit of gas turbine blade material. Combustion product temperature is controlled by making A/F mixture a lean mixture. Gases coming out from gas turbine have large amount of thermal energy. Major part of this thermal energy is transferred to compressed air in regenerator and high pressure water in heat recovery steam generator (HRSG). Flue gas temperature at HRSG outlet depends upon the dew point temperature of flue gases. Temperature below dew point causes the corrosion of stack by flue gases.

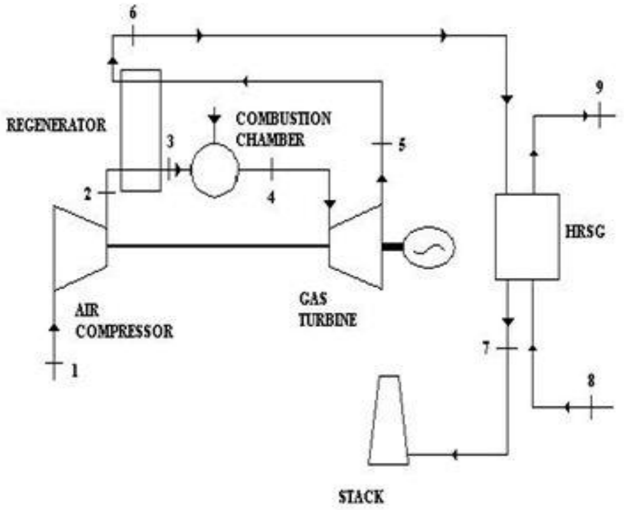

Figure 1 schematic diagram of CHPS

In the present work, mathematical modeling based on mass, energy and exergy balance across each component based on the different cycles operational parameters by the execution of the computer program in the Software Engineering Equation Solver (EES). Exergy-based cost analysis aims at determining the costs of products and irreversibility's (exergy destroyed) generated in energy conversion processes,

III. EXERGY DESTRUCTION IN GAS TURBINE CYCLE

The system is a steady state, continuous flow condition and operates in the non-reaction gases arbitrarily void thermo mechanical enthalpy, entropy, and exergy at the condition of ambient pressure and temperature regardless of their chemical composition. The entropy of mixing of different gas components can be neglected and general exergy- balance equation is given by

$$\dot{E}_w = \sum_{i=1}^{n} (\dot{E}_Q)_i + \sum_{in} \dot{m}e - \sum_{out} \dot{m}e - \dot{E}_D$$

For single stream flow

$$\dot{E}_w = (\dot{E}_Q) + \dot{m}\, e_{in} - \dot{m}\, e_{out} - \dot{m}\, e_D$$

Specific exergy is given by

$$a_f, e = T \left[(C_{pa} + wC_{pv}) \left(\frac{T}{T_0} - 1 - \ln\left(\frac{T}{T_0}\right) \right) + (1+\bar{w}) R_a \ln\left(\frac{p}{p_0}\right) \right] + R T_0 \left[(1+\bar{w}) \ln\left(\frac{1+\bar{w}}{1+w}\right) + \bar{w} \ln\left(\frac{\bar{w}}{w}\right) \right]$$

$$T_0 (s_g - s_c) \quad \varepsilon_p = 1 - \frac{\ }{(h_g - h_c)}$$

E_Q And E_W are the corresponding exergy of heat transfer and work which cross the boundaries of the control volume and subscript (a) refers to the ambient conditions respectively. The exergy factor of process heat depends on steam conditions and is given by the following relation

IV. MATHEMATICAL MODELING OF EXERGY EQUATION AND EVALUATION SPECIFIC EXERGY OF FUEL

Exergy of fuel is depend on two major component first is ξ (fuel constant) and second is lower heating value of fuel, the value of ξ depend upon no. of hydrocarbon (no. of carbon atom & no. of hydrogen atom), ignition capability of fuel is depend upon lower heating value of fuel.

$e_f = \xi \times LHV$
e_f = Specific exergy of fuel
LHV = Lower heating value of fuel
ξ = fuel constant

The value of fuel constant is referring from thermal energy conversion

$$\xi = 1.033 + 0.169\frac{y}{x} - \frac{0.0698}{x}$$

Fuel constant depend main internal property of fuel consider no. of carbon & hydrogen atom $C_x H_y$ or CH_4.
No. of hydrogen atom=4
No. of carbon atom= 1
The value of x =1 , y = 4 depend upon no. of hydrocarbon, then find value of fuel constant
ξ=1.0308

Already known value of Lower heating value of fuel for 30MW gas turbine cogeneration cycle

$$LHV = 50196.96 \frac{kJ}{kg}$$

After find value of □ (fuel constant), Lower heating value of fuel then can be find exergy of fuel (CH_4)

Refer previous equation

$$e_f = \xi \times LHV$$

$$LHV = 50196.96 \frac{kJ}{kg}$$

$$\xi = 1.0308$$

$$e_f = 51743.026 \frac{kJ}{kg}$$

Consider costs of methane is approximate equal to CNG Price 35.20 INR, then find cost of exergy destruction in each component of power plant for per unit fuel consumption.

V. RESULT & DESCUSSION

5.1 Effects of Turbine Inlet Temperature on Cost of exergy destruction in Sub-system

Based on Developed method and equations derived in the previous sections, the change in turbine inlet temperature (TIT) calculated the cost of exergy destruction for each the cost of exergy destruction is increase 24.96 to 27.46 INR, the cost of exergy destruction in cycle at 1000 C is 24.96 INR & the cost of exergy destruction in cycle at 1400 C is 27.46 INR then have been save 7.10 % exergy destruction cost when operate at 1000 C .the result also show that cost of exergy destruction is minimum at 1000 C than other TIT. Component of gas power plant, with the changes in the turbine inlet temperature (TIT) respectively the cost of exergy destruction in different component of power plant is recorded in (TABLE 4.12). Turbine inlet temperature 1000°C to 1400°C increases proportionately with cost of exergy destruction are found in cogeneration cycle is increase respectively 70.90 to 78.02 %, these represent 70.90% cost of fuel are losses in exergy destruction from total cost of unit fuel and it may observe 7.12% of cost of fuel save when operate plant cycle at lower turbine inlet temperature (TIT). Brief study cost loss due to exergy destruction in each component of gas turbine power plant with respect to turbine inlet temperature (TIT) show in (TABLE 4.12).

Cost of exergy Destruction per unit fuel flow (INR) =exergy destruction in sub-system(kJ/kg) ×Price of per unit Fuel (kg/s) / Specific exergy of Fuel (kJ/kg)

5.2 Cost Loss due to exergy destruction in Cycle with respect to TIT

The turbine inlet temperature are increase from 1000 to 1400 °*C* in cogeneration cycle respectively the cost of exergy destruction is increase 24.96 to 27.46 INR, the cost of exergy destruction in cycle at 1000 °*C* is 24.96 INR & the cost of exergy destruction in cycle at 1400 °*C* is 27.46 INR then have been save 7.10 % exergy destruction cost when operate at 1000 °*C* .the result also show that cost of exergy destruction is minimum at 1000 °*C* than other TIT

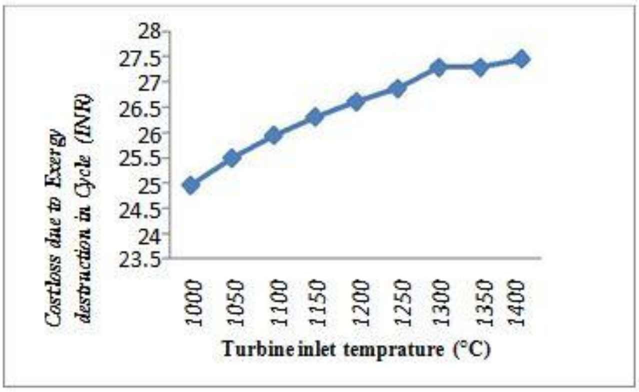

Figure 2 Effect of TIT on cost loss due to exergy destruction in cycle

5.3 Effects of Cycle Pressure Ratio on Cost of Exergy destruction in Sub-System

Based on equations derived in the previous sections, the change in cycle pressure ratio (CR) calculated the cost of exergy destruction for each component of gas power plant. With the changes in the cycle pressure ratio (CR) correspond the cost of exergy destruction in different component of power plant is recorded in (TABLE 4.13) and also represent optimum cycle pressure ratio at which gas turbine cycle performance is best & exergy destruction is minimize in sub system of power plant. From the (TABLE 4.13), it can be observe that the Cycle's pressure ratio 5 to 26 increases proportionally with exergy destruction are found affected in each component of gas power plant. cycle pressure ratio effect the cost of exergy destruction in each component of the system,

5.4 Cost Loss due to exergy destruction in Cycle with respect to CR

From above explanation it can observe cost loss due to exergy destruction with respect to CR in sub-system. now analysis cost of exergy destruction in cycle for per unit fuel flow from observe the (TABLE 4.13) it is representing that the cycle pressure ratio varies from 5 to 26 respectively the cost of exergy destruction in gas turbine cycle is reducing from 29.78 to 25.04 INR up to CR-15 & after that cost of exergy destruction is increase respectively up to CR-26. cost of exergy destruction in cycle at CR-5 is 29.78 INR, cost of exergy destruction in cycle at CR-15 is 25.04 INR it represent that 13.47% cost of exergy destruction is save as & gas turbine cycle operate at above CR-15 to CR-26 cost of exergy destruction is increase. Cycle performance becomes negligible at above CR-26, when compare exergy destruction cost at CR-26 to CR-15 then it find that 10.23% cost of exergy destruction is save.

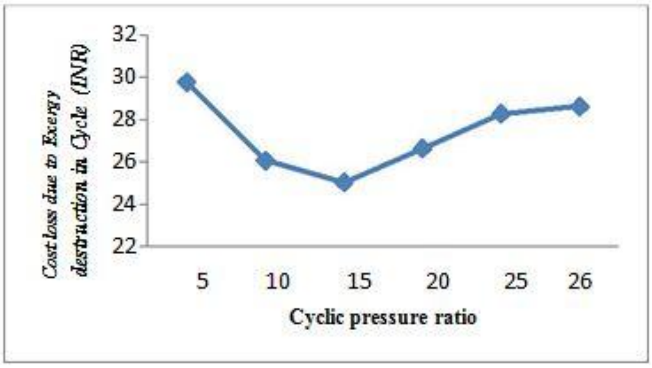

Figure 3 Effect of CR on cost loss due to exergy destruction in cycle

A cost of methane is approximate equal to CNG Price 35.20 INR and assumes that the cost of 1kg fuel purchase is 35.20INR explain previous. now from this evaluation it being find that the cost of exergy destruction in cycle at CR-15 is 25.04 INR is subtract from cost of per unit fuel purchase then it find that 28.86% cost of exergy destruction save up to several year and backup the cost of installation as revenue until cycle operate at CR-15 then compare to other CR. cost of exergy destruction at CR-26 is 28.64 INR above table result 3.60 INR cost of exergy destruction is increase at CR-26.

VI. CONCLUSIONS

- find that 10.16 INR cost of exergy destruction save up to several year until cycle operate at CR-15 then compare to other CR in gas turbine cogeneration cycle.
- Cost loss due to exergy destruction In Gas Turbine Cogeneration Cycle is increase with Turbine inlet Temperature (TIT).
- Cost loss due to exergy destruction in Gas Turbine Cogeneration Cycle is decrease initial up to CR-15, after that increase up to CR-26.
- Implement the backup period of plant installation cost with the help of improve cost loss due to exergy destruction in each component of power plant cycle.
- With the help of simulation tool exergy analysis of any thermodynamic cycle available in a market are easier.
- From the analysis it is revealed that energy analysis alone is not enough to analysis the cogeneration cycle, as exergy analysis leads to better interpretation of the results. With the help of the methodology developed in this paper, the major source of energy and exergy destruction may be identified and may be formulated accordingly improved cogeneration cycle.

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TABLE I TIT effect on cost of exergy destruction in sub-system of power plant

EVALUATION OF PRIES FOR EXERGY DESTRUCTION									
Turbine Inlet Temperature (°C)	**1000**	**1050**	**1100**	**1150**	**1200**	**1250**	**1300**	**1350**	**1400**
Cost of Ed in CC (INR)	18.03	17.89	17.74	17.58	17.42	17.26	16.95	16.94	16.79
Cost of Ed in AC (INR)	2.23	2.1	1.82	1.66	1.54	1.42	1.24	1.24	1.16
Cost of Ed in HRSG (INR)	1.04	1.83	2.56	3.22	3.85	4.42	5.46	5.46	5.92
Cost of Ed in R (INR)	0.47	0.91	1.23	1.45	1.63	1.74	1.89	1.89	1.92
Cost of Ed in GT (INR)	3.18	2.86	2.59	2.37	2.19	2.03	1.77	1.77	1.66
Cost of Ed in Cycle (INR)	24.96	25.5	25.94	26.31	26.62	26.62	27.29	27.29	27.46

From the (TABLE 4.12), it is represented that the cost of exergy destruction in sub-system of gas power plant is affected with respect to turbine inlet temperature.

TABLE II CR effect on cost of exergy destruction in sub-system of power plant

EVALUATION OF PRIES FOR EXERGY DESTRUCTION						
Cycle pressure ratio (CR)	**5**	**10**	**15**	**20**	**25**	**26**
Cost of Ed in CC (INR)	18.02	17.06	16.55	17.12	17.83	17.98
Cost of Ed in AC (INR)	1.34	1.43	1.56	1.67	1.8	1.83
Cost of Ed in HRSG (INR)	4.28	3.89	3.6	4.39	4.92	5.01
Cost of Ed in R (INR)	4.58	1.65	0.88	0.58	0.47	0.46
Cost of Ed in GT (INR)	1.56	2.04	2.47	2.87	3.26	3.34
Cost of Ed in Cycle (INR)	29.78	26.07	25.04	26.64	28.28	28.64

