Energy Conversion and Management 101 (2015) 371–378

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Thermodynamic and exergoeconomic analysis of Çayırhan thermal power plant

Ali Bolatturk, Ahmet Coskun *, Caglar Geredelioglu

Department of Mechanical Engineering, Suleyman Demirel University, 32260 Isparta, Turkey

ARTICLE INFO

Article history:
Received 12 February 2015
Accepted 31 May 2015
Available online 11 June 2015

Keywords:
Exergy
Thermal power plant
Exergoeconomic
Efficiency

ABSTRACT

It is an indisputable fact that much saving could be achieved provided that the efficiency of thermal plants, which bear a huge share in the distribution of generated energy, could be increased by making certain improvements and minimize the losses. These practices as a natural consequence shall provide useful benefits to find a solution for energy problem.

In the current study exergy and thermoeconomic analyses of Turkey-based Çayırhan thermal power plant have been conducted. Thermodynamic properties of the inlet and outlet points of each unit in thermal plant have been specified via EES package program. With the help of obtained thermodynamic properties, thermal and second law efficiencies of thermal power plant have been found respectively as 38% and 53%. In thermal power plant, the highest amounts of exergy losses are witnessed alternatively in; the boiler, turbine groups, condenser, heater group and pump groups. The highest amount of exergy loss costs are seen respectively in boiler, turbine group and condenser. When exergoeconomic factors are examined, the highest factor has been measured in turbine group, which is followed respectively by boiler and condenser drain pump.

1. Introduction

What needed most is not the use of energy but effective use of energy to secure a sustainable future. Hence exergy term and exergy analysis bear unprecedented value for mankind. Energy and exergy analysis combination is an analysis method treating the primary and secondary laws of thermodynamics collectively and referring to the maximum usability of energy.

Identifying power plants and making improvements on these plants is of great importance to minimize the loss of generated energy. That corresponds to boosting the efficiency and maximizing power generation. To develop the efficiency and power of energy plants, many technologies have been developed and currently being developed. Today one of the most widely used plants is thermal plants. Thermal power plants are the kind of facilities transforming chemical energy inherent in solid, liquid and gas fuels into thermal energy, which is then converted to electrical energy. In sum thermal power plants are the facilities that derive electrical energy from the chemical energy of fossil power. Fossil power plants are set into three groups with respect to the type of fuel they use; solid fuel (coal and brown coal), liquid fuel (Fuel–Oil), gas fuel (natural gas).

In relevant literature there is a wide body of researches on the performance analyses of thermal power plants. Ehyaei et al. [1] in their study have examined the effects of an additional unit to the inlet of a typical power plant in Iran on the first and second law efficiency. Additionally, a new optimization is suggested in their study for system optimization. Inside this new function there are certain parameters such as first law efficiency, energy cost and external cost that is creating air pollution in the system. It has been detected in the end that with the addition of a unit to the inlet of plant, outlet power, first and second law efficiencies have respectively risen by 7%, 5.5% and 6% and 4% slump could be detected in energy and pollution costs. Li and Liu [2] in their research have specified detailed exergy losses of a thermal plant with 300 MW outlet power on the basis of second law of thermodynamics. Exergy analyses have shown that the greatest exergy loss in the plant was seen in boiler unit. They have noted that exergy efficiency and loss analyses of power plant provided contribution to trouble-shooting and correcting. On a combined cycle plant, Ahmadi et al. [3] have performed thermodynamic modeling, exergy, exergoeconomic analysis and optimization. It has been noted that the highest exergy loss in combined cycle plants is in boiler. The reasons have been attributed to the irreversibility during combustion and the excessive temperature difference between combustion gases and working fluid. Exergoeconomic analyses have shown that the greatest exergy loss cost is seen in

* Corresponding author. Tel.: +90 246 211 1253.
E-mail address: ahmetcoskun@sdu.edu.tr (A. Coskun).

http://dx.doi.org/10.1016/j.enconman.2015.05.072
0196-8904/

Nomenclature

A	valuation factor
BFT	boiler feed tank
C	cost of unit exergy ($/kJ)
$\dot{C}$	total exergy cost ($/h)
C_F	chemical symbol of the fuel
C_1	chemical symbol of environmental reactant
C_λ	chemical symbol of environmental product
CELF	fixed escalation correction factor
CRF	capital recovery factor
e	specific exergy (kJ/kg)
$\dot{E}$	exergy rate (kW)
e^{CH}	chemical exergy (kJ/kg)
$\bar{e}^{CH}$	standard molar chemical exergy (kJ/kmol)
h	enthalpy (kJ/kg)
HPH	high pressure heater
HPT	high pressure turbine
IP	improvement potential
i_{eff}	payback ratio
$\dot{I}$	irreversibility (kW)
k	price correction factor
LPH	low pressure heater
LPT	low pressure turbine
MPT	medium pressure turbine
$\dot{m}$	mass flow rate (kg/s)
n	operational life (year)
P	product
$\dot{Q}$	heat (kW)
R	reactant
r_n	regular increase ratio
s	entropi (kJ/kg K)
T	temperature (°C)
υ_1	stoichiometric coefficients of environmental reactants per mole of fuel
υ_λ	stoichiometric coefficients of environmental products per mole of fuel
$\dot{W}$	power (kW)
$\dot{Z}$	investment cost rate of components ($/h)
f	exergoeconomic factor
$\bar{g}$	molar Gibbs function (kJ/kmol)
μ	chemical potential (kJ/kmol)
η	efficiency

Subscripts

0	dead state
r	reversible
HE	heat exchanger
Cond	condenser
th	thermal
e	exergy

combustion chamber. It has also been emphasized that the rise in the input heat to gas turbine creates a decreasing effect on the exergy loss cost of the plant.

Rosen and Dincer [4] in their study made a different selection of dead state conditions, thus applied energy and exergy analysis to a coal-fired power plant. By applying energy and exergy analysis separately to the whole system as well as system components, they have reached an analysis of the results.

Ünal [5] in his research applied thermoeconomic analysis on the second unit of operating thermal power plant in Turkey and conducted thermoeconomic analysis and assessment for each of equipment units. For each of equipment, independent energy and exergy balances have been set to compute average exergy costs; lost and damaged energy and exergy have been detected; lost exergy ratio has been calculated to obtain exergoeconomic factors. The equipment which could be corrected has been identified by establishing connection between analysis results and suggestions for solution have been presented.

Tsatsaronis and Park [6], in their study based on a cogeneration system, analyzed the effects of preventable and unpreventable exergy consumptions in the thermodynamic analysis of heat systems and cost analysis of system components. In each component of the system exergy balances have been established; average exergy costs have been detected and exergoeconomic factors have been obtained. They have emphasized that particular attention should be paid to preventable exergy consumption and investment costs could be decreased by defining the parts in which exergy consumption could be lowered. Lee et al. [7] investigated exergetic and exergoeconomic evaluations of a 100 kW-class solid-oxide fuelcell-based combined heat and power generation system. Besides the paper has been find out the measures that would improve its efficiency and cost effectiveness. For the analyses, the exergies of fuel and the exergies of product for all components have been defined. Subsequently, the exergetic efficiency of each component has been evaluated. Ganjehkaviri et al. [8] presented a study on a comprehensive thermodynamic modeling of a combined cycle power plant (CCPP). The study is conducted the exergoeconomic analysis in order to determine the cost of electricity and cost of exergy destruction. In addition, a comprehensive optimization study is performed to determine the optimal design parameters of the power plant. The results have shown that by using the optimum values, the exergy efficiency increases for about 6%, while CO_2 emission decreases by 5.63%. However, the variation in the cost was less than 1% due to the fact that a cost constraint was implemented. Mert et al. [9] have performed exergoeconomic analysis of a cogeneration plant at Erdemir, Turkey. In their study was done the exergoeconomic analysis of the plant with the mass, energy and exergy balances. The exergoeconomic analysis of the plant with a 39.5 MW electricity and 80 ton/h steam production capacity, was performed. El-Emam and Dincer [10] in their study made the thermodynamic and economic analyses on a novel-type geothermal regenerative organic Rankine cycle based on both energy and exergy concepts. An optimization study was also performed based on the heat exchangers total surface area parameter. The energy and exergy efficiency values were found to be 16.37% and 48.8%, respectively, for the geothermal regenerative organic Rankine cycle. Manesh et al. [11] investigated the optimum integration of a steam power plant as a source and a site utility system as a sink of steam and power using exergy, exergoeconomic and exergoenvironmental analyses. The results shown that integration of a steam power plant and a site utility system is an advantageous option from exergetic, economic, exergoeconomic and exergoenvironmental viewpoints. Geredelioglu [12] in his research performed energy, exergy and thermoeconomic analysis of a thermal power plant which is still active in Turkey. According to these determinations, energy and exergy of each node were measured. The levels of beneficial power, reversible power and irreversible power of each of equipment of the system were detected, general efficiency of the system was measured, and exergoeconomic factors were found out by determining the disappearing exergy ratios.

In this study, thermodynamic properties of the input and output of the unit of Çayırhan thermal power plant were determined by EES software package. With the help of these properties, energy