Renewable and Sustainable Energy Reviews 56 (2016) 454–463

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Energy and exergy analysis of Montazeri Steam Power Plant in Iran

Gholam Reza Ahmadi, Davood Toghraie

Department of Mechanical Engineering, Khomeinishahr Branch, Islamic Azad University, Khomeinishahr, Iran

ARTICLE INFO

Article history:
Received 30 December 2014
Received in revised form
22 November 2015
Accepted 30 November 2015

Keywords:
Energy analysis
Exergy analysis
Irreversibility
Mohammad Montazeri Power Plant
Steam power plant repowering

ABSTRACT

This paper aims at investigating steam cycle of Shahid Montazeri Power Plant of Isfahan with individual unit capacity of 200 MW. Using mass, energy, and exergy balance equations, all cycle equipment have been analyzed individually and energy efficiency, exergy efficiency, and irreversibility has been calculated for each of them as required. EES (Engineering Equation Solver) software is used for performing analyses. Values and ratios regarding heat drop and exergy loss have been presented for each equipment in individual tables. The results from the energy analysis show that 69.8% of the total lost energy in the cycle occurs in the condenser as the main equipment wasting energy, while exergy analysis introduces the boiler as the main equipment wasting exergy where 85.66% of the total exergy entering the cycle is lost.

Contents

1. Introduction . . . 454
 1.1. Power plant cycle description . . . 456
2. Analysis . . . 456
 2.1. Boiler . . . 457
 2.2. Fuel exergy . . . 458
 2.3. Calculating chemical exergy of gases leaving the boiler . . . 458
 2.4. Calculating exergy of the air entering the boiler . . . 458
 2.5. Turbine . . . 458
 2.6. Condenser . . . 458
 2.7. Closed feed water heater . . . 459
 2.8. Open feed water heater . . . 459
 2.9. Pump . . . 459
3. Cycle analysis . . . 460
4. Conclusions and recommendations . . . 460
References . . . 463

1. Introduction

In many countries, steam power plant cycles have been discarded from the power generation cycle due to low efficiency, environment pollution, and especially insufficient fossil resources and have been replaced by the power plants with high efficiency and economic and technical justification. In Iran as well many research have investigated in recent years using new and green energies in spite of plenty available fossil fuels resources. Accordingly, using wind power, solar energy, nuclear power and other energies have been recommended. However, the power supply network's demand for high speed in installing and implementing power plants and good capabilities of steam power plants in this aspect has made using them justifiable. Also, availability of fossil fuels in Iran is another reason contributing justifiable utilization of these power plants. As up to 80% of the power generated in the world is produced through energy conversion from power plants working with fossil fuels (such as fuel oil, light crude oil, gasoline, and natural gas) and the rest from the other resources

E-mail address: Toghraee@iaukhsh.ac.ir (D. Toghraie).

http://dx.doi.org/10.1016/j.rser.2015.11.074
1364-0321/

Nomenclature

B	Boiler
$\dot{I}_{des}$	Destroyed exergy (kW)
$\dot{m}$	Mass flow rate (kg/s)
$\bar{R}$	World constant for gases
BFP	Boiler feed pump
C	Condenser
CP-1st	First stage condensate pump
CP-2nd	Second stage condensate pump
CT	Cooling tower
CWP	Circulating water pump
DE	Deaerator
DP	Drip pump
e	Specific energy (kJ/kg)
E	Total energy (kJ)
EJ	Ejector
Ex	Flow exergy
EXP	Expansion valve
G	Generator
g	The gravity of Earth (m/s^2)
GC	Gland condenser
GCO	Gland cooler
GV	Governing valve
h	Specific enthalpy (kJ/kg)
HPH	High pressure heater
HPT	High pressure turbine
IPT	Intermediate pressure turbine
LPH	Low pressure heater
LPT	Low pressure turbine
P	Pressure (bar)
PP	Polishing plant
Q	Heat (kw)
s	Specific entropy (kJ/kg K)
T	Temperature (°C)
v	Velocity (m/s)
W	Work (kW)
z	Elevation (m)
Ql	Heat loss (kW)

Greec symbols

η_1	First low efficiency
η_2	Second low efficiency
ψ	Specific exergy (kW/kg)

Subscripts and superscripts

0	Reference conditions of ambient
a	Air
des	Destroyed
g	Gas
i	Inlet
o	Outlet

such as dams, nuclear power, wind power, solar energy, geothermal power and other energies [1] and also as major power plants in our country are of steam cycle type [2], it is necessary to carry out enough research toward optimizing the cycle of these power plants. Using the first and second laws of thermodynamics as available and useful tools for analyzing energy and exergy of power conversion systems seems an appropriate method. In this way, one can know the extent of heat loss and irreversibility of the processes. Exergy analysis flourished in recent years is an appropriate method toward understanding the processes through which some solutions for optimal usage of existing power plants can be developed [3]. Exergy analysis is a useful tool to represent the difference between energy losses and internal irreversibilities in a process [4]. Kotas and Szargut [5,6] used exergy analysis method for thermal, chemical, and metallurgical analyses of power plants. Kotas [5] has used Grossman diagrams in which any single flow is defined by its own exergy to determine the flow exergy in a system. He also points to thermo-economic issues and economic optimizations of thermodynamic systems. Exergy analysis is an appropriate method for measuring performances of process components. By this method, exergy of the points in which energy conversion takes place can be obtained, efficiencies of cycle components are calculated, and the place where the largest losses happen can be also identified and the steps can be in turn taken to decrease them [7]. Rosen and Dincer [8] introduce exergy analysis the best tool for deciding on optimization of the cycle with respect to the input information.

Vosoogh [9] performed energy and exergy analyses on the boiler of a steam power plant and concluded that decreasing combustion excess air from the fraction 0.4–0.15, energy and exergy efficiencies respectively increase to 0.19% and 0.37%. Also, reducing the temperature of the smoke leaving the chimney from 137 °C to 90 °C, the above efficiencies respectively increase to 0.84% and 2.3%. Abdussaeid Ganji et al. [10] analyzed energy and exergy of the equipment in Heat Recovery Steam Generators in combined-cycle power plants in order to develop an optimization plan. Among the parameters investigated in this research were drum pressure and arrangement of heat exchangers in Heat Recovery Steam Generators for high and low pressure parts. Kaushik et al. [11] analyzed energy and exergy in Rankine cycle and combined-cycle power plants. Among the differences between this research and other similar cases are detailed description of the process and providing all the equations required for simulating each equipment in Rankine cycle and combined-cycle, which can be good references for future works. They concluded that while the largest energy loss happens in the condenser, the largest exergy loss occurs in the boiler and during combustion process. This can be due to the incomplete combustion process, inappropriate heat insulation and entropy generation in the device. Reddy et al. [12] revealed interesting results in exergy analysis. They found that combustion chamber of gas turbine produces the largest exergy in the whole cycle so that increasing pressure ratio in gas turbine compressor can decrease exergy loss in other equipment. Ameri et al. [13] analyzed exergy of the combined-cycle power plant (420 MW) of Neka, Iran. Their results showed that combustion chamber, gas turbine, duct burner, and heat recovery steam generator are the main sources of irreversibility which comprise 83% of the total exergy loss of the power plant. The main source of exergy loss was also recognized to be the combustion chamber of gas turbine. The second source of exergy generation was heat recovery steam generator whose improvement can reduce the exergy loss of the power plant. Isam Aljundi [14] performed energy and exergy analysis in alhossein power plant in Jordan and concluded that by preheating the air entering the boiler and reducing fuel to air ratio, exergy loss in boiler (known as the main factor of exergy loss) can be reduced. Ahmadi et al. [15] performed energy and exergy analyses in steam power plant of Hamedan and investigated the effect of environment temperature changes and unit load variations on total efficiency and concluded that preheating the air entering the boiler causes an increase in efficiency so that it is better that power plant always works in its nominal load in order to