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Simulation of a thermal power plant with district heating: Comparative results of 5 different codes

João G.S. Fonseca Jr, Paulo S. Schneider*

Thermal and Energetic Group, Mechanical Engineering Department, Federal University of Rio Grande do Sul, Rua Sarmento Leite, 425—90050-170—Porto Alegre, Brazil

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Abstract

This paper presents a simulation code for the thermal power plant AVV1, located in Copenhagen, Denmark, in response to the challenge launched at the ECOS 2003 congress. The simulation program was specially created for this contest, including the calculation of the thermodynamic properties of water, as based on IAPWS97. Every component of the plant is modeled through mass and energy balance equations, and the solution of the whole system is achieved by a successive substitution scheme. The plant is simulated in two operation modes: generating electricity only, and generating electricity and district heating simultaneously. In the first operation mode, four series of simulations are run for loads varying from 40% to 100%. Each series assumes different hypotheses with respect to the variation in the isentropic efficiencies and pressures of the groups that form the turbine. In the second mode, the plant is simulated with a 100% load. An exergetic analysis of the plant, in the two modes analyzed, is presented. The generated results are compared with those presented by several researchers who have tackled the problem. The comparison shows that the results presented here agree most satisfactorily with the results presented in the literature.

Keywords: AVV1; Power plant; Combined heat and power plant; Exergy; Thermodynamic properties of steam; IAPWS-IF97

1. Introduction

The motivation of the present paper was answering a challenge proposed during the conference on Efficiency, Costs, Optimization, Simulation and Environmental Impact of Energy and Process Systems—ECOS2003. The challenge consisted of simulating a real thermo-electrical plant, currently in operation. The sponsors of the contest aimed at making a comparison between simulation programs for thermal power plants, with no constraints on the nature of the programs. The different groups that replied to the challenge used either commercial or academic programs. The starting point was the document provided by the organizers [1] and each participant had to use their own models to simulate equipments and system. Furthermore, it was required that each one developed their own interpretations and chose particular

*Corresponding author. Tel.: +55 51 3316 3931; fax: +55 51 3316 3355.
E-mail address: pss@mecanica.ufrgs.br (P.S. Schneider).

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Nomenclature

$\dot{m}$	mass flow rate (kg/s)
B_i	static pressure in the outlet of the group (kPa)
h	specific enthalpy (kJ/kg)
IR	irreversibility
k	isentropic coefficient
p	pressure (kPa)
s	specific entropy (kJ/(kg K))
T	temperature (K or °C)
v	specific volume (m^3/kg)
$\dot{W}$	generated power (kW)
Y_{iD}	Stodola's constant (m^{-2})

Greek symbols

ϕ	constant flow coefficient (m^2)
η	isentropic efficiency, [−]
η_{EXERG}	exergetic efficiency, [−]

Subscripts

D	design conditions
i	nozzle index
1	inlet
2	outlet

simplification hypotheses in order to solve the problem. The ensuing variety of interpretations enriched the discussion of the results. The plant chosen for the study works in two modes, generating electricity only or both electricity and district heating (cogeneration). The aim is to simulate the plant in these two different modes of operation, for a broad range of loads, but always on steady state.

For the present paper, it was decided to build a full-fledged simulation code, including the calculation routines for thermodynamic properties of water, based on IAPWS97 [2]. For the mode in which the plant generates electricity only, the simulation covers operation loads varying from 40% to 100%, and the focus of the study was on assessing the influence of the hypotheses regarding the modeling of a steam driven turbine. The simulation in cogeneration mode was always carried out on full load, thus allowing for the comparison of the results with those provided by the other participants in the contest. For both cases, exergetic analysis of the plant and its main equipment are presented.

2. Problem description

The plant chosen by the contest sponsors is the pulverized coal Avedϕrevaerket, unit 1, located in Copenhagen, herein referred to as AVV1. It is basically composed of a coal-fired steam generator, a turbine and an electric generator, four pre-heaters and four regenerators, three heat exchanges for the cogenerations mode and a condenser. The plant operates under super-critical conditions in design conditions, with temperature and steam pressure on the inlet of the turbine at 540 °C and 24 MPa, respectively. In addition, the cold circuit of the plant condenser works with seawater, admitted at 10 °C. The turbine has five groups: the first one works with high-pressure fluids, two of them at intermediate pressure and another two at low pressure. In the cogeneration mode, the low pressure groups are deactivated and the fluid at the outlet of the intermediate pressure groups is directed towards the district heaters.